

NASA CR-189363

NAS 5-26555

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# Hubble Space Telescope Cycle 5 Call for Proposals

**Proposal Deadlines:**    **August 12, 1994 (paper plus electronic)**  
                                  **July 29, 1994 (paper only)**

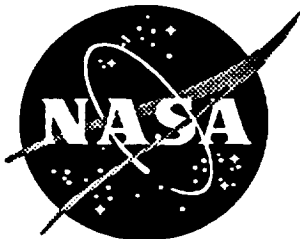
(NASA-CR-189363) HUBBLE SPACE  
TELESCOPE CYCLE 5 CALL FOR  
PROPOSALS (Space Telescope Science  
Inst.) 58 p

N94-36279

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G3/89 0014034

**Issued June 1994**



STScI SC-02

This is the fifth *Call for Proposals* for astronomical observations with the *Hubble Space Telescope* by members of the international scientific community. The *Call for Proposals* was prepared in the Science Program Selection Office at the Space Telescope Science Institute, with input from the entire STScI staff. Comments and suggestions for improvement are invited, and should be addressed to:

Science Program Selection Office  
Space Telescope Science Institute  
3700 San Martin Drive  
Baltimore, MD 21218  
USA

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Director

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# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE June 1994	3. REPORT TYPE AND DATES COVERED Contractor Report	
4. TITLE AND SUBTITLE  Hubble Space Telescope Cylce 5, Call for Proposals			5. FUNDING NUMBERS  633	
6. AUTHOR(S) Howard E. Bond, Editor				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Space Telescope Science Institute 3700 San Martin Drive Baltimore, MD 21218			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, D.C. 20546-0001			10. SPONSORING/MONITORING AGENCY REPORT NUMBER  CR-189363	
11. SUPPLEMENTARY NOTES  Technical Monitor: R. Dilling, Code 633				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified-Unlimited Subject Category 82 Report is available from the NASA Center for AeroSpace Information, 800 Elkridge Landing Road, Linthicum Heights, MD 21090; (301) 621-0390.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  This document invite and support participation by the international astronomical community in the HST General Observer and Archival Research programs. These documents contain the basic procedural and technical information required for HST proposal preparation and submission, including applicable deadlines. The telescope and its instruments were built under the auspices of the NASA and the European Space Agency.				
14. SUBJECT TERMS Hubble Space Telescope			15. NUMBER OF PAGES 53	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited	



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# PART I: POLICIES AND PROCEDURES

## 1. Introduction

This document invites proposals for participation in the fifth round ("Cycle 5") of the General Observer and funded Archival Research programs of the *Hubble Space Telescope* (*HST*). The telescope and its instruments were built under the auspices of the National Aeronautics and Space Administration and the European Space Agency, and management of *HST*'s scientific program has been assigned to the Space Telescope Science Institute (STScI).

*HST* is a 2.4-m telescope that was carried into orbit on April 24, 1990, aboard the orbiter *Discovery*. Until the end of 1993, its performance was affected by the primary mirror's spherical aberration, which was discovered shortly after launch. The first *HST* servicing mission, carried out by the *Endeavour* astronauts in December 1993, restored the optical performance for which the telescope was originally designed, and corrected several other problems that had arisen since launch. Cycle 4 observations are now underway, and Cycle 5 observing will begin in mid-1995.

*HST*'s Scientific Instruments (SIs) include two cameras, two spectrographs, and the spacecraft fine guidance system. The principal capabilities of the *HST* observatory include high-resolution optical and ultraviolet imaging, ultraviolet spectroscopy, and astrometry and interferometry. At this writing, the spacecraft systems and instruments are, with very few exceptions, functioning nominally.

Part I of this document gives a summary of the policies and procedures for proposing Cycle 5 *HST* observations and for requesting funding to support research on archival *HST* data. Part II provides an overview of *HST*'s current technical capabilities. Further detailed information about the telescope and each SI is provided in documents that are available from STScI as described in §2. Enclosed with this *Call for Proposals* are the *HST Phase I Proposal Instructions*, which contain blank proposal forms and detailed instructions for obtaining the corresponding machine-readable proposal templates, preparing them, and submitting them electronically and on paper.

Since the proposal forms and submission procedures have been modified and simplified significantly for Cycle 5, it is important that all proposers, including those who proposed in previous cycles, read this document and the accompanying *Instructions* carefully. Proposers should particularly note the following features of Cycle 5:

- Cycle 5 observing will commence nominally on July 1, 1995, and have a duration of 12 months.
- Cycle 5 observing proposals may request use of any of the Scientific Instruments (WFPC2, FOC, FOS, GHRS, and FGS), with the sole exception that proposals may not be submitted for use of the FOC  $f/48$  camera. Side 1 of the GHRS is now available for routine observations, following the repair mission.
- The proposal form used in previous cycles has been replaced with two  $\text{\LaTeX}$  templates (one for observing proposals, and another for archival research proposals). Proposers are asked to submit hardcopy paper printouts of the form to STScI, and additionally to submit the  $\text{\LaTeX}$  file by electronic mail. STScI will make photocopies of the hardcopy proposal for use by the reviewers, so that proposers now need submit only two paper copies instead of the former 20.
- In addition, an experimental all-electronic proposal submission is now being offered, for observing proposals only.

- No Budget Forms or estimated funding requirements need be submitted with observing proposals. However, archival proposers are requested, as in previous cycles, to submit complete Budget Forms.
- Beginning with Cycle 5, observers will be allocated spacecraft "orbits," instead of the spacecraft "hours" that were allocated in previous cycles. The procedure for calculating the required number of orbits for a given program is described in detail in the *Phase I Proposal Instructions*. The advantages of allocating orbits include the increased accuracy of the resource-usage estimates provided in Phase I, and the greater degree of program optimization that is achieved when observers take target viewing times into account.

As in previous cycles, there will be separate proposal submission deadlines depending on whether (1) proposals are submitted entirely on paper, or (2) the filled-in L<sup>A</sup>T<sub>E</sub>X template file is sent to STScI by electronic mail in addition to the paper proposal. In the former case, the deadline is earlier because of the required computer entry of proposal data by STScI personnel. Paper-only submissions require an accompanying cover letter in which the proposer certifies that he/she is unable to submit the proposal electronically. For the experimental electronic-only submission, the deadline is the same as for the paper-plus-electronic submission.

The Cycle 5 proposal deadlines are as follows:

Paper-plus-electronic submissions: **August 12, 1994**

Paper-only submissions: **July 29, 1994.**

Unfortunately, because of the processing steps that must commence immediately upon receipt, it will not be possible to consider proposals that are submitted after these deadlines.

## 2. Sources of Further Information

All proposers should read the entire *Call for Proposals* in order to understand the policies and procedures for preparing and submitting observing proposals, and to gain an overview of the *HST* and its capabilities.

Observing proposals will contain a summary of the proposed observing programs, including the targets that are to be observed and their celestial coordinates, and the desired instrument modes and filters or dispersers. In addition, a calculation of the number of spacecraft orbits needed to accomplish the observing program must be carried out and summarized in the proposal. Thus it is important that proposers consult technical documentation about the capabilities and sensitivities of the instrument(s) that will be used to obtain the observations. Where necessary, proposers should discuss their requirements with appropriate STScI experts before submitting their proposals. The following subsections describe the various sources of information that are available to proposers.

### 2.1 User Support Branch

The User Support Branch (USB) of the Science Programs Division at STScI serves as the central point of contact between the scientific community and the Institute. The USB provides general and specific observatory information, supports proposal processing, and provides logistical support to users who visit STScI.

Questions and requests may be directed to USB as follows:

*Mail:* The postal address is:

User Support Branch  
Space Telescope Science Institute  
3700 San Martin Drive  
Baltimore, MD 21218 USA

*Telephone:* 800-544-8125 (toll-free within the U.S.) or 410-338-4413.

*Facsimile machine:* 410-338-5085 (USB machine for use by proposers, GOs, and GTOs only) or 410-338-4767 (general use).

*Electronic mail:* usb@stsci.edu.

## **2.2 Technical Documentation**

New editions of the detailed technical handbooks have been prepared for each of the Scientific Instruments (SIs), reflecting instrument performance following the servicing mission. A new *HST Data Handbook* is now available, describing the data that are produced by each SI. In addition there are documents describing the *HST* data-analysis software (STSDAS) and the Synphot software for estimating instrument count rates and exposure times. For Archival Researchers a "primer" and a detailed manual are available. There is also a catalog of the GO and GTO observing programs that have already been accepted, which is available electronically from STScI (see §2.4) and from the ST-ECF (see §2.6 and the "Archive" column in recent issues of the ST-ECF *Newsletter* for details). Proposers with no network access may obtain a hardcopy of this catalog from the USB.

The paper documentation set is available in most institutional libraries. Proposers are urged to use their library copies of these documents to the fullest possible extent. Individual copies may, however, be requested from the USB.

The current set of technical documents is listed in Table 1a. Table 1b lists the WF/PC and HSP manuals, which have not been updated due to the removal of these two instruments from the spacecraft, and are now of interest primarily for archival proposers and for those analyzing pre-refurbishment data.

Updates to the technical information contained in these documents are provided in the STScI *Newsletter* and through the Space Telescope Electronic Information Service, both of which are described below. Proposers should consult both of these sources for the latest updates when preparing their proposals.

## **2.3 STScI Newsletter**

STScI publishes a *Newsletter* at regular intervals. The STScI *Newsletter* contains information of interest to proposers, including updates on the status of the *HST* and its instruments. Subscriptions are available at no cost to all interested scientists upon request to the USB.

## **2.4 Space Telescope Electronic Information Service**

The Space Telescope Electronic Information Service (STEIS) provides access to a wide variety of *HST*-related information, including the latest updates on mission schedules and status, spacecraft and instrument performance, proposal deadlines, and data-analysis software.

**Table 1**  
**HST Technical Documentation**  
**(a) Current Documentation**

Document	Version	Issue Date
<i>Call for Proposals</i>	Cycle 5	June 1994
<i>Phase I Proposal Instructions</i>	4.0	June 1994
<i>WFPC2 Instrument Handbook</i>	2.0	May 1994
<i>FOC Instrument Handbook</i>	5.0	May 1994
<i>FOS Instrument Handbook</i>	5.0	May 1994
<i>GHRS Instrument Handbook</i>	5.0	May 1994
<i>FGS Instrument Handbook</i>	4.0	May 1994
<i>HST Data Handbook</i>	1.0	February 1994
<i>STSDAS User's Guide</i>	1.3	April 1994
<i>Synphot User's Manual</i>	1.3	September 1993
<i>HST Archive Primer</i>	4.1	June 1994
<i>HST Archive Manual</i>	4.0	February 1994

**(b) Documentation for Retired Instruments**

Document	Version	Issue Date
<i>WF/PC Instrument Handbook</i>	3.0	April 1992
<i>HSP Instrument Handbook</i>	3.0	April 1992

There are three ways to access the information available on STEIS. The first and generally easiest is via the World-Wide Web (WWW), using a client such as Mosaic for X-windows, Macintosh, or MS-Windows (from the National Center for Supercomputing Applications), or Lynx for ASCII terminals (from the University of Kansas). For proposers with access to one of these WWW clients, the URL (Universal Resource Locator) which gives access to the STEIS "page" is

**<http://stsci.edu/steis.html>**

From this page proposers can follow the WWW hypertext links to find the information of interest.

The second access method is via "Gopher," which provides a menu-like interface to the files on the STScI server. Those with access to the xgopher program for X-windows can start a session to browse the STScI server directories by issuing the command

**`xgopher stsci.edu`**

Detailed descriptions of Gopher (including how to obtain the software) may be found in the September 1993 STScI *Newsletter* and in the August 1993 ST-ECF *Newsletter*.

The third (and generally least convenient) way to access information on STEIS is via anonymous file transfer protocol (ftp). This allows users with Internet access to connect to

the STScI server machine (stsci.edu or 130.167.1.2) to browse and retrieve files of interest. Users who are not familiar with ftp procedures should consult with their local network experts, refer to the instructions printed in recent issues of the STScI *Newsletter*, refer to *The STEIS Guide* (available from USB upon request), or contact USB for assistance.

## 2.5 STScI Staff Contacts

Proposers who have detailed questions that can be answered by technical experts at STScI are invited to contact those persons. A list of staff contacts is provided in Appendix A1.

## 2.6 Space Telescope European Coordinating Facility

As a supplement to the USB services, the Space Telescope European Coordinating Facility (ST-ECF) provides *HST* information to European astronomers. Questions and requests may be directed to the ST-ECF as follows:

*Mail:* The postal address is:

ST-ECF  
Karl-Schwarzschild-Str. 2  
D-85748 Garching bei München  
Germany

*Telephone:* +49-89-320-06-291 *Fax:* +49-89-320-06-480

*Electronic mail:* ST-ECF has a special account for *HST*-related inquiries, whose address is stdesk@eso.org. There is also an anonymous ftp account from which *HST*-related programs and data can be downloaded: ecf.hq.eso.org (or 134.171.11.4).

For details of electronic access, including access through the WWW, see articles in recent issues of the ST-ECF *Newsletter*. The *Newsletter*, although aimed principally at European *HST* users, contains articles of general interest to the *HST* community. Those who wish to subscribe should contact the *Newsletter* Editor at the ST-ECF.

## 2.7 Canadian Astronomy Data Centre

Canadian proposers may obtain assistance from the Canadian Astronomy Data Centre (CADC). Questions and requests may be directed to the CADC as follows:

*Mail:* The address is:

CADC/DAO  
5071 W. Saanich Rd.  
Victoria, B.C. V8X 4M6  
Canada

*Telephone:* 604-363-0025

*Electronic mail:* cadc@dao.nrc.ca

## 3. Proposal Categories

Proposals will be selected for the General Observer (GO) program and for the funded Archival Research (AR) program through a competitive peer-review process. A portion of the observing time has been awarded to Guaranteed Time Observers (GTOs). It is also possible to submit requests for Director's Discretionary time for extremely urgent observations. These various proposal categories are described in the following subsections.

### 3.1 General Observer Proposals

#### 3.1.1 Scope of GO Proposals

Observing proposals may request any scientifically justified amount of observing time. Programs are classified according to the amount of time requested as "small" (less than 100 spacecraft orbits) and "large" (100 or more orbits, summed over all cycles in the case of long-term proposals).

Requests for observing time in previous cycles have exceeded the available time by factors of approximately 6 to 8, and it is likely that *HST* observing time will again be oversubscribed heavily by the Cycle 5 proposals.

#### 3.1.2 Target-of-Opportunity Proposals

Proposals will normally identify one or more specific astronomical objects (or "targets") that will be observed. However, it is possible to submit proposals to observe unpredictable transient phenomena (such as novae or supernovae, or newly discovered comets). For such proposals it may not be possible to include a list of specific objects; instead, the proposer may specify "generic targets" (see the *Proposal Instructions* for details). The proposal should present a detailed plan of observations that will be implemented if the specified event occurs; it should also provide an estimate of the probability of occurrence of the specified event during the 12-month observing cycle.

Target-of-opportunity proposals will be peer reviewed through the normal procedures. An accepted program will be executed only in the event that the specified phenomenon actually occurs, and *it will be the responsibility of the GO to inform STScI of the occurrence of the phenomenon*. The implementation cannot occur until a detailed observing plan is in place. See §16 for a discussion of constraints on the time interval between a notification and the actual initiation of the observations, and on the allowable number of such interruptions of the observing schedule per year. If the event does not occur during the observing cycle, the program will be deactivated at the end of the cycle.

In the event of a sudden phenomenon of an unanticipated nature, for which it is felt that *HST* observations should be initiated on an urgent basis, a request for Director's Discretionary time may be submitted (see §3.4).

#### 3.1.3 Long-Term Programs and Continuation Proposals

GO programs will normally be completed within the current scheduling cycle. However, a few long-term programs (i.e., observing programs having a duration of more than one cycle) may also be accepted. Large projects (see below) will often be long-term programs, since typically no more than 100 orbits will be allocated to a given project during a single cycle.

Long-term programs also include projects that require a long time baseline, but not necessarily a large total number of spacecraft orbits, in order to achieve their scientific goals. Typical examples of such projects might be astrometric observations or long-term monitoring of variable stars or active galactic nuclei. Proposals for long-term status should be limited to the most exceptional cases where such status is clearly required scientifically. The scientific necessity for an allocation of time extending beyond Cycle 5 should be presented in detail.

Long-term programs may be approved for durations of up to three observing cycles. New long-term proposals should describe the entire requested program and should provide a cycle-by-cycle breakdown of the number of orbits requested. See the *Phase I Instructions* for details.

A Cycle 5 *continuation proposal* is required from GOs who wish to continue long-term programs for which Cycle 5 time was already tentatively approved in Cycle 3 or 4. If satisfactory progress is being made, and the need for continuing *HST* observations is justified, the Telescope Allocation Committee (TAC) may recommend that the program continue to receive observing time in Cycle 5. However, because of the large oversubscription of *HST* time, the TAC will consider the scientific importance of the continuation requests relative to newly proposed programs, and it may modify the proposed continuation program or, in some cases, not recommend further observations.

As noted in the *Proposal Instructions*, continuation proposals should provide summary information for the entire project, along with a cycle-by-cycle breakdown of the requested spacecraft orbits, including previously allocated time (in spacecraft hours for Cycle 4 and earlier allocations). However, the observation summary table in the proposal should specify only the visits for Cycle 5, not the proposed visits for future cycles nor those approved for past observing cycles.

#### 3.1.4 Large Projects

Proposals for large projects (i.e., projects requesting  $\geq 100$  spacecraft orbits, as defined in §3.1.1) are invited for Cycle 5, and will be seriously considered by the TAC.

It is particularly important that a large proposal should define an optimum database to be obtained by *HST*, should outline the methods by which the data will be analyzed, and should demonstrate that the proposers possess sufficient expertise to assure a thorough, coordinated analysis of the observational data. Where possible, the observations should be obtained in a manner that will make them suitable for purposes beyond those relevant to the large project, even if the proposing team does not itself plan to carry out such analyses.

As discussed in §3.1.3, large projects will sometimes be long-term programs (i.e., they will last more than one scheduling cycle). As for all long-term programs, proposals for the execution of large projects lasting more than one observing cycle should present an observing plan for the full project, with a breakdown of the observations among the cycles (see the *Proposal Instructions*). Yearly continuation proposals are required for all ongoing long-term programs, including large projects, as described above.

Proposals for the conduct of large projects will be reviewed competitively through the normal process applicable to other categories of *HST* observing time, but will receive special scrutiny (as described in §6.2.2) because of their large demands on *HST* resources. *Selection of a large project for implementation does not necessarily rule out acceptance of smaller projects in the same field, although scientific duplication and overall program balance will be considered.*

### 3.2 “Snapshot” Survey Proposals

In the process of optimizing the *HST* observing schedule (as described in §7.2), the scheduling algorithm occasionally finds short time intervals during which it is impossible to schedule any exposures from the pool of accepted programs. In order to utilize these intervals for scientific observations, STScI has developed the capability to take short survey exposures (“snapshots”) on objects selected from a large list of candidates.

Snapshot observations are placed on the schedule only after the observing sequence has been determined for the higher-priority targets. The gaps in the schedule that are appropriate for snapshot exposures are short, no more than a single target visibility period and frequently less than 20 minutes. In certain cases, the guide-star acquisition can be

omitted for snapshot exposures, which will then be taken under gyroscopic control, whose tracking performance is described in §11.2. Past experience shows that there are several opportunities per week for snapshot exposures, or about 200-300 per year.

Astronomers are invited to propose lists of candidate snapshot targets for Cycle 5 through the normal peer-review process. Snapshot proposals should provide a discussion of the target sample and the potential use of the survey images by the investigator and the astronomical community, specify the number of candidate targets in the sample, and provide a typical example of a snapshot exposure, including the instrument and mode, exposure time, and filter.

Snapshot survey proposals that use instruments other than the WFPC2 will be considered. These non-WFPC2 exposures require the acquisition of guide stars (to ensure that the instrument aperture does not drift onto objects too bright for the instrument).

Snapshot proposers are urged to consider waiving the normal one-year proprietary data rights.

Snapshot proposers should consider the following guidelines:

- Each guide-star acquisition, target acquisition, exposure, and readout should require no more than approximately 30 minutes, and preferably less than about 20 minutes.
- The observations should be as straightforward as possible, with a minimum of filter or grating motions.
- Only fixed targets should be proposed (due to the large additional effort involved in scheduling observations of moving targets).
- Snapshot proposals should specifically identify the requested guiding mode and the requested proprietary data-rights period for the exposures, for consideration and allocation by the peer reviewers.

Snapshot proposers should be aware that snapshot time allocations are not guaranteed; the number of observations actually executed will depend on the availability of appropriate schedule gaps. Continuing improvements in scheduling efficiency and the allocation of observing time by spacecraft orbits are expected to reduce the size and number of gaps available for snapshots.

### **3.3 Funded and Non-Funded Archival Research Programs**

Completed *HST* observations, including both GO and GTO data, become available to the community upon expiration of their proprietary periods. The data are archived at STScI and are available for analysis by interested scientists through the *HST* Archival Research (AR) program. A copy of the *HST* archives is also maintained at the ST-ECF in Garching, to which European requests should normally be addressed, and the CADC will have a copy as well.

See §9 for an overview of the present contents of the archive, and for details of the procedures for accessing archival *HST* data.

Funding for U.S. astronomers is expected to be available during Cycle 5 to support the analysis of archival data. Proposals for AR funding during Cycle 5 will be considered at the same time, and by the same reviewers, as proposals for GO observing time for Cycle 5, and the deadlines for submission of funded AR proposals are the same as for GO proposals. The review of AR proposals will be based on scientific merit and other appropriate criteria, as discussed in §6.2.3.



Proposals for funded AR should be submitted on the special AR proposal form. As in the case of observing proposals, the form should be submitted both in hardcopy (two copies) and by electronic mail. An electronic submission is required of all AR proposers, since by definition they will all have access to U.S. electronic mail. Detailed Budget Forms should be submitted with the paper copies of the Phase I proposal. Instructions for preparing AR proposals are given in the *Phase I Proposal Instructions*. Each archival proposal should include an estimate of the total number of data sets that will be analyzed.

Scientific programs that require both funding for archival research and new observations should be submitted as two separate proposals, one requesting funding for the AR, and the other proposing the new observations. The proposals should refer to each other so that the reviewers will be aware of both components of the proposed project.

It is permissible to submit long-term (i.e., multi-year) AR proposals, subject to the usual annual submission of a continuation proposal as outlined in §3.1.3, in cases where the scope of an AR program requires long-term status. This requirement must be clearly justified in the proposal.

### 3.4 Director's Discretionary Proposals

Up to 5% of the available *HST* observing time may be reserved for Director's Discretionary (DD) allocation. A proposal for DD time might be appropriate in cases where a truly unexpected transient phenomenon occurs, when developments since the last proposal cycle make a time-critical observation necessary, or when it is desired to obtain high-risk observations with a low *a priori* probability of success but considerable scientific importance if successful. In practice, very few non-time-critical DD proposals are approved; in general, such authors are encouraged to resubmit their proposals for the next peer-review cycle.

As discussed elsewhere in this document, the *HST* observing schedule is determined several months in advance of the actual observations. Although it is technically feasible to interrupt the schedule and initiate observations of a new target within as little as 48 hours, such short-notice interruptions place very severe demands on the planning and scheduling process and are limited to about ten times per year. Hence requests for DD time must be extremely well justified and, if at all possible, submitted at least three months before the date of the requested observations. In view of the long lead times, it will in many cases be more appropriate to submit a proposal through the normal GO procedures (perhaps as a target-of-opportunity program) than to request DD time.

Proprietary periods for DD programs will generally be shorter than the usual 12 months described in §7.5; especially in the case of an unexpected target of opportunity, the Director may make the data non-proprietary and available immediately to the astronomical community. However, DD proposers may request and justify longer proprietary periods in their proposals.

Scientists wishing to request DD time should do so by submitting three copies of a proposal on the current Phase I paper forms, accompanied by a letter describing the need for discretionary time, to the User Support Branch. The "proposal category" should be used to indicate that the request is for DD time. Such proposals may be submitted at any time.

The Director will usually seek advice on the scientific merit and technical feasibility of such requests from STScI staff or outside specialists before taking action. The primary criterion for acceptance is extremely high scientific merit, with a strong requirement of demonstrated urgency.

### 3.5 Guaranteed Time Observer Programs

The National Aeronautics and Space Administration (NASA) has awarded a portion of the observing time during the first several years of *HST* operations to scientists involved in the development of the telescope and its instruments. These scientists are the Guaranteed Time Observers (GTOs).

Some of the original GTO programs have been deferred to after the refurbishment mission, and in addition the WFPC2 science team has been awarded approximately 200 hours of spacecraft time to be used during the first two years following the servicing mission. Approximately 25% of the observing time during Cycle 5 will be assigned to the GTOs.

### 3.6 Duplications among GO and GTO Observations

This subsection discusses several aspects of observations that may duplicate observations that have already been obtained with *HST*, or are currently in the pool of accepted *HST* programs. An observation is defined as duplicating a previous one if it is on the same astronomical target, with the same or similar instrument, a similar instrument mode, and a similar spectral range. It is the responsibility of proposers to check their proposed observations against the catalog of previously executed or accepted programs (see below), and, if any duplications exist, to identify and justify them in the Phase I proposal.

Under NASA policy, the GTO programs (described in §3.5) are protected against contemporaneous acquisition by the GOs of duplicate observations. Proposed GO observations that are judged to infringe upon this protection will be disallowed. However, the duplication protection is as specifically defined above; entire classes of objects or broad scientific programs are not protected. The GTOs are entitled to revise their programs after each cycle of GO selection, but they in turn may not duplicate the previously approved GO programs. The protection of each observation is in force throughout its proprietary data-rights period (see §7.5), and then expires.

New GO programs are not formally prohibited from duplicating previously accepted GO programs, but a close scientific match could result in a lower ranking during the peer review, in view of the limited *HST* resources. The same could of course be true in the case of similarities with GTO programs that are not identically duplicated.

A catalog of all past and planned GO and GTO observing programs will be available by anonymous ftp from STEIS (§2.4), or it can be examined interactively using StarView (§9.1); most proposers will find StarView the easier and more productive method. This catalog will consist of two parts: a list of exposures, and the scientific abstracts for each program. If necessary, a hardcopy version of this catalog may be obtained upon request from the USB.

Prospective GOs should examine the catalog and exposure lists carefully before submitting their proposals, to ensure that they have not duplicated these programs, and should be aware of the risks associated with proposing exposures and scientific objectives that are closely similar to either the GTO or the approved GO programs. If there are duplications, they must be identified and justified in the Phase I proposal. In particular, similar exposures on targets in protected GTO programs must be justified strongly as meeting significantly different and compelling scientific objectives. Without specific TAC recommendation to retain such exposures, STScI will remove or restrict them during the duplication checks that are made in Phase II.

## 4. HST Observation Types

### 4.1 Primary Observations

#### 4.1.1 Overview

Since all of the Scientific Instruments (SIs) are located at fixed positions in the telescope focal plane, it is possible to operate two SIs simultaneously, thereby increasing the scientific productivity of *HST*. *Primary* observations are defined as those that determine the telescope pointing and orientation. They will always have operational priority over *parallel* observations made with a second SI (see §4.2).

Primary observations are scheduled at times that maximize telescope efficiency, and in most cases the GO will not need to be present at STScI during the execution of the observations. However, special considerations regarding scheduling and execution of observations may come into play under the circumstances described below.

#### 4.1.2 Time-Critical Observations

Proposals may request that *HST* observations be made at a specific date and time, or within a range of specific dates. Examples of time-critical observations for which such requests would be appropriate include, but are not limited to, the following: (1) astrometric observations; (2) observations of specific phases of binary or pulsating stars; (3) monitoring of variable stars or galactic nuclei; (4) imaging of surface features on rotating solar-system bodies; (5) observations that require a specific telescope orientation (since the orientation is fixed by the date of observation, as discussed in §10.2); (6) observations that must coincide with simultaneous ground-based or other space-based experiments; and (7) observations required to be repeated at some time interval.

Time-critical events that occur over time intervals short compared to the orbital period of *HST* (such as eclipses of very short-period binary stars) introduce an additional complication because it will not be known, until a few weeks in advance, where *HST* will be in its orbit at the time of the event, and hence whether it will occur above or below the spacecraft's horizon. Proposals to observe such events can therefore be accepted only conditionally. A more detailed discussion of this problem is given in §13.3.

Because of the constraints that time-critical observations impose on the *HST* scheduling system, the scientific justification for such requests should be presented in detail in the observing proposal.

#### 4.1.3 Real-Time Observations

The usual purpose of a real-time interaction will be to carry out an interactive target acquisition, either with the same SI to be used for the scientific observations, or with a camera followed by an offset to the required SI (see §§14.3.1 and 15, and the *Instrument Handbooks* for technical details).

Availability of the Tracking and Data Relay Satellite System and other constraints limit real-time interactions to a few per week. Real-time observations generally require additional operational overheads, and thus reduce observing efficiency. Hence real-time interactions are a limited resource, and the scientific and operational justification for such interactions should be presented clearly in the observing proposal.

Real-time observations will generally require the GO's presence at STScI during the exposures.

## 4.2 Parallel Observations

Parallel observations are observations made with a second SI while another SI is carrying out a primary observation. An essential difference between primary and parallel observations is that the latter are made solely on a basis of non-interference with the associated primary observations.

Since each SI samples a different portion of the *HST* focal plane (see Fig. 3, §12.7), an SI used in parallel mode will normally be pointing at a "random" area of sky several minutes of arc away from the primary target. Thus parallel observations are usually of a survey nature. However, many *HST* targets lie within extended objects such as star clusters or galaxies, making it possible to conduct parallel observations of nearby portions of, or even specific targets within, these objects.

Parallel observations of the following types may be proposed:

1. *Pure parallel observations.* In this case, a proposal is submitted for parallel observations that are unrelated to any specific primary observations. Proposals for such programs may involve either specific or generic targets; however, the latter are more common. Appropriate scheduling opportunities for such observations will be identified by STScI.

2. *Coordinated parallel observations.* In this case, the GO requests use of two SIs simultaneously, typically in order to observe two adjacent targets or regions within an extended object. Proposals for coordinated parallel observations should present a description of a coherent scientific program that clearly requires simultaneous usage of two SIs.

Some examples of possible parallel programs may clarify these concepts:

1. A proposal could be submitted that would call for a WFPC2 frame to be obtained whenever one of the other SIs is carrying out an observation at a galactic latitude  $|b| > 45^\circ$ . The aim of such a program might be to carry out star counts at faint magnitudes, or to search for distant QSOs or galaxies. This is an example of pure parallel observations.

2. A proposal could request that a WFPC2 image be obtained whenever another SI is observing any target in a region centered on a specific position (such as that of M87 or NGC 4565). Here the aim might be to conduct a survey of the globular clusters surrounding the galaxy, or to search for luminous stars or H II regions. Such a proposal could be submitted either as a pure parallel program (on the plausible assumption that other GOs will submit successful proposals to observe these galaxies with *HST*), or as a coordinated parallel program (if the GO were planning other kinds of observations of the same galaxies).

Technical discussions of parallel observations are given in §17 and in the *Instrument Handbooks*.

Since most parallel observations will involve use of the WFPC2, proposers should be aware that the area of sky covered is only a few square arcminutes. Thus proposals for parallel observations should demonstrate that useful scientific results can be obtained from coverage of a small area of the sky.

## 5. Proposal Submission

### 5.1 Who May Submit

Proposals for *HST* observing time may be submitted by scientists of any nationality or affiliation, and may request use of any of the SIs. Each proposal must identify a single individual who will act as Principal Investigator (PI), but should also list all Co-Investigators

(Co-Is) who will be involved in the analysis of the data. The PI will be responsible for the scientific and administrative conduct of the project, and will be the formal contact for all communications with STScI. All proposals will be reviewed without regard to the nationalities or affiliations of the proposers.

An agreement between NASA and the European Space Agency (ESA) states that a minimum of 15% of *HST* observing time (on the average over the lifetime of the *HST* project) will be allocated to scientists from ESA member states. It is anticipated that this requirement will continue to be satisfied via the normal selection process, as it has been in previous cycles. In order to monitor the allocation to scientists from ESA member states, STScI requests that *each PI and Co-I whose affiliation is with an ESA member-state institution be identified as such in the list of investigators contained in the proposal.*

Proposals for funded Archival Research may be submitted only by scientists affiliated with U.S. institutions. Similarly, only U.S. scientists may request funding from STScI for GO programs. See §5.5 and Appendix 2 for details.

## 5.2 What to Submit

Detailed instructions for preparing and submitting proposals are given in the accompanying *Phase I Proposal Instructions*. In summary, there are three submission options:

- Submission of both a paper proposal and an electronic proposal file. This is the “standard” procedure for the majority of proposers. The submission deadline is August 12, 1994. It is the only option offered for Archival Research proposals.
- Submission of a paper proposal only. This is allowed only for the small number of observing proposers without access to electronic mail, and the deadline is July 29, 1994.
- Submission of an electronic proposal file only. This is a new experimental option for observing proposals only, with the same August 12 submission deadline; however, persons interested in using this option must contact the USB at least two weeks before the deadline for further information and instructions.

The following is an overview of these three options.

### 5.2.1 Paper-plus-Electronic Submission

Under this option, observing and Archival Research proposals are submitted in both electronic and paper form.

**Two (2) complete, single-sided copies** of the paper proposal should be submitted to STScI. U.S. proposers who are requesting funding for Archival Research should also include Budget Forms GF-95-1, GF-95-2, and GF-95-3 (attached to both copies of the proposal), containing the required institutional signatures.

Note that the Budget Forms *are not required for observing proposals*. Budget Forms will be requested in Phase II from successful U.S. observers only.

Student PIs should enclose one copy of the certification letter from a faculty advisor, as described in §5.3.

Photocopies of the paper proposals will be made at STScI for use by the reviewers. Hence the proposals should not be submitted in bound copies, nor with any special covers. The STScI copies will be black-and-white Xeroxed copies. Proposers who are concerned about the quality of the STScI copies, perhaps because the proposals include high-quality illustrations (including color images), may submit **twenty (20)** paper copies, which will then be the copies seen by the reviewers.

Blank copies of the proposal and budget forms and detailed instructions for filling them out are contained in the *Phase I Proposal Instructions*.  $\LaTeX$  templates for the proposal forms (but not the Budget Forms) should be downloaded from STEIS. The identical filled-in templates should be used to prepare the paper forms for submission, and should be submitted electronically to satisfy the electronic-submission requirement. Note that the paper and electronic forms used in previous cycles *are not acceptable*.

*Proposals that are illegible, incomplete, not written in English, or not submitted on the Cycle 5 Phase I forms will not be accepted.*

The electronic submission is required of all proposers who have the capability to send electronic mail to or within the U.S., and is in addition to the required submission of the two copies of the paper forms.

### 5.2.2 Paper-only Submission

If the proposal is being submitted *only* on the paper forms, a cover letter should be attached explaining why an electronic submission is impossible. (The usual explanation would be that the proposer is located in a country without easy access to U.S. electronic mail.)

Note that the submission deadline for paper-only proposals is two weeks earlier than for paper-plus-electronic submissions, in order to reflect the significant additional STScI processing effort.

Paper-only Archival Research proposals will not be accepted, since by definition all funded AR proposers will be U.S. investigators.

### 5.2.3 Full Electronic Submission (Experimental Option)

For Cycle 5 STScI is offering a fully electronic submission procedure on a limited experimental basis. In this mode of submission, the proposer still sends via electronic mail the filled-in  $\LaTeX$  proposal template, but instead of the paper copies sends the PostScript output file from  $\LaTeX$  (which may incorporate any desired monochrome figures as encapsulated PostScript). STScI will print out and copy all of the paper hardcopies required during the peer-review process.

Proposers who are interested in taking advantage of this option should contact the USB to indicate their interest, and to receive further information and instructions, no later than two weeks before the electronic deadline.

This submission mode is not available for Archival Research proposals, due to the required signed paper Budget Forms.

## 5.3 Endorsements

Endorsement signatures are not required for Phase I observing proposals (unless required by the regulations of the proposing institution); such endorsements will be requested in Phase II from successful GOs only.

However, endorsement signatures (those of the PI and of an authorized institutional official) are required for funded Archival Research proposals, due to the required inclusion of Budget Forms.

Proposals for observing time from *student PIs* will be considered. Each such proposal should be accompanied by a written statement from the student's faculty advisor certifying (1) that the student is qualified to conduct the observing program and data analysis; and

(2) that the student is in good academic standing. If the research is part of a doctoral thesis, the proposal should so indicate. (The faculty advisor's statement is not required in cases where a student is listed in the proposal only as a Co-I.) Students should, however, be particularly aware of the inherent uncertainties of space-based research and of the possible impact of delays upon their educational progress.

#### **5.4 Where and When to Submit**

The paper proposal copies should be submitted to the User Support Branch at STScI, as described in the *Phase I Proposal Instructions*.

All electronic submissions should be made to a special account at STScI (new-prop@stsci.edu), again as described in detail in the *Instructions*.

*It is the responsibility of applicants to transmit their proposals early enough to assure arrival in Baltimore by the appropriate deadline.* Proposals received after the deadline cannot be processed. All proposals must be complete at the time of submission, and it will not be possible to modify proposals between the deadline for submission and the meetings of the peer reviewers.

For accounting purposes, *scientists from ESA member states who are listed as PI or Co-I must also send one electronic or paper copy of the proposal to the ESA HST Project Scientist, as described in the Instructions.*

#### **5.5 Funding of U.S. Observers and Archival Researchers**

Subject to availability of funds from NASA, STScI will provide financial support for *U.S. observers and U.S. Archival Researchers only*. Detailed policies that apply to such funding are discussed in Appendix A2 of this document. ARs wishing to apply for such support should submit Budget Forms, as described above and in the *Phase I Proposal Instructions*. Successful observers will be requested to provide the Budget Forms as part of their Phase II submissions.

For successful observing proposals submitted by non-U.S. PIs with U.S. Co-Is who request funding, one of the U.S. Co-Is should be designated as administratively responsible for the STScI funding, and should collect and submit the budget forms for all of the U.S. Co-Is in Phase II.

Proposers from ESA member states should note that ESA does not fund *HST* research programs. Therefore, successful ESA member-state proposers should seek any necessary resources from their respective home institutions or national funding agencies. ESA observers do, however, have access to the data-analysis facilities and technical support of the staff of the ST-ECF (see §2.6).

#### **5.6 Proposal Confidentiality**

Proposals submitted to STScI will be kept confidential to the maximum extent consistent with the review process described below. However, all Phase II information for accepted programs will be publicly accessible, including PI and Co-I names, project titles, abstracts, description of observations, special scheduling requirements, and details of all targets and exposures.

## 6. Phase I: Proposal Evaluation and Selection

The process by which *HST* proposals will be reviewed and selected for implementation is described in this section. Prospective GOs will find it useful to have an understanding of this process as they prepare their proposals.

"Phase I" refers to the process from proposal preparation and submission through the selection of a recommended list of accepted programs by the peer reviewers and the Director's approval. "Phase II," which is discussed in §7, refers to the detailed program preparations (including specifications of the actual *HST* exposures in complete detail) that are subsequently carried out by the GOs who have been approved for observing time.

### 6.1 Technical and Duplication Review

The first step in the evaluation of a proposal is its technical review by STScI. This is carried out partly by computer and partly by a careful reading of the proposal by a STScI staff member. Any technical or feasibility problems that become apparent will be brought to the attention of the peer reviewers.

Any cases of GTO duplication (which are not allowed according to the policies discussed in §3.6) that may come to the attention of the peer reviewers could lead to rejection during the Phase I deliberations. A final systematic computer-aided check for duplications of previous GTO observations is carried out in Phase II.

Since a portion of the review will be accomplished by computer, *it is essential that the proposal forms and electronic files be filled out in accordance with the Phase I Proposal Instructions.*

### 6.2 Scientific Review

The evaluation of the scientific merit of proposals will be accomplished via a two-stage peer-review process, which is managed by the Science Program Selection Office (SPSO) at STScI. Proposals will be ranked according to a well-defined set of criteria (see below) by committees of scientists chosen from the world astronomical community, in order that a final recommended *HST* program may be transmitted to the STScI Director.

#### 6.2.1 Subdiscipline Review Panels

In the first stage of the scientific review, each proposal will be considered in detail by the appropriate expert panel. There will be eight panels, corresponding to the eight scientific categories that may be selected on the first page of the proposal form: Active Galactic Nuclei, Cool Stars, Galaxies & Clusters, Hot Stars, Interstellar Medium, Quasars, Solar System, and Stellar Populations.

The outcome of the panels' deliberations will be recommended allocations of spacecraft orbits (for observing proposals) or funding levels (for AR proposals), and ranked lists of proposals within each scientific category.

#### 6.2.2 Telescope Allocation Committee

The final recommended GO and AR programs will be selected from the ranked lists by the Telescope Allocation Committee (TAC), which will be composed of the chairpersons of the review panels, plus a similar number of interdisciplinary scientists who were not members of individual panels. The aim of the TAC will be to integrate the panel recommendations into a balanced overall scientific program for *HST*.



Because of their large demands on *HST* resources, proposals for large projects will receive special attention during the review process. The TAC will make its recommendations regarding the large projects before the panels consider the small proposals, so that the impact of the large projects on the overall *HST* program may be taken into account. A preliminary balance among the subdisciplines will also be recommended at that time.

The TAC will place the programs into one of three pools (accepted, supplemental, or unaccepted). The accepted and supplemental pools are described below (§7.3).

### 6.2.3 Selection Criteria

The review panels and TAC will base their evaluations of *HST* observing proposals (and, where appropriate, AR proposals) on the following criteria:

- ☐ The scientific merit of the proposed project and the importance of its contribution to the advancement of scientific knowledge.
- ☐ The technical feasibility and likelihood of success of the project.
- ☐ The requirement of the unique capabilities of *HST* in order to achieve the scientific goals of the program (e.g., evidence that the project *cannot* be accomplished with ground-based telescopes).
- ☐ Evidence that the project has already been pursued to the limits of ground-based and/or other space-based techniques.
- ☐ Evidence of collaborative and coordinated effort to maximize the scientific return from the observational program, especially for large projects.
- ☐ The demands made on *HST* and STScI resources, including the efficiency with which telescope time will be used.

In the evaluation of proposals to conduct large observing projects, the panels and TAC will use the following additional criteria:

- ☐ Evidence that a plan exists for assembling a coherent database that will be adequate for addressing all of the purposes of the large project.
- ☐ Evidence that the proposers possess sufficient expertise to assure a thorough analysis of the database.
- ☐ Evidence that the work of the proposers will be coordinated effectively, even though a large team may, in some cases, be required for the proper analysis of the data.
- ☐ Evidence that the observational database will be obtained in such a way that it will be useful to the maximum possible extent for purposes beyond the immediate goals of the large project.

## 6.3 Allocation of HST Observing Time

The TAC will make its recommendations to the STScI Director, who will make the final allocation of observing time.

Beginning with Cycle 5, the time recommended by the TAC and approved by the Director will be in units of "spacecraft orbits." Directions and worksheets for calculating the required number of orbits are given in the *Phase I Proposal Instructions*; they take into account the actual on-target exposure time, plus the overhead time spent acquiring guide stars and placing the targets in the desired instrument apertures, reacquiring guide stars after Earth occultation, preparing the instruments for the observations, and reading out the data.

All proposers will receive written notification of the outcome of the selection process. It is anticipated that the panels and TAC will meet approximately 2.5 months after the electronic proposal submission deadline, and that the written notifications of the Phase I outcome will be sent shortly thereafter.

## **7. Phase II: Program Definition, Scheduling, and Execution**

This section provides an overview of the interactions that will occur between STScI and GOs whose observing programs have been approved.

### **7.1 Phase II Observation Specifications**

The information supplied by GOs in their Phase I proposal forms is only at a level necessary for the technical and scientific review of the project, but is not detailed enough for actual definition and scheduling of the observations. Successful GOs will be asked to submit additional detailed "Phase II" observation specifications so that their programs can actually be placed on the observing schedule for execution.

The Phase II submission deadline will be approximately eight weeks after the notification of the TAC outcome. The Phase II information that GOs will submit will include (1) new versions of the general proposal information, revised, where necessary, to conform to the TAC's recommendations; (2) a target list, containing accurate coordinates, fluxes, and other target information, including, for solar-system targets, a "target pointing specification"; and (3) a list of visits and exposures, containing full details of the desired observations, including instrument configurations and modes, apertures, filters or dispersers, exposure times, and any special exposure requirements (such as the timing of the observations, telescope orientation, and acquisition modes). U.S. GOs will also submit their detailed Budget Forms at this time.

Extensive computer software has been developed at STScI for the processing of the Phase II information and its transformation into actual commands to the spacecraft. GOs will submit their Phase II information in a completely electronic form, using the Remote Proposal Submission System (RPSS). Details of RPSS, including software (downloadable from STEIS) for preparing and validating the Phase II submission, will be provided to all successful proposers.

For complex or difficult programs, STScI encourages observers to visit STScI before the Phase II deadline. Observers may incur preaward travel costs to support such visits, and financial support for such visits may be included in the Phase II budget and in a preparatory funding request. However, it should be noted that all preaward expenditures are incurred at the risk of the PI and that all funding is contingent upon the availability of funds from NASA at the time the award is made.

### **7.2 Science Planning and Scheduling**

In order to provide efficient utilization of scarce *HST* observing time, STScI will prepare the observing schedule by selecting dates of optimal target visibility and by interleaving the individual observations of many different programs. Thus a typical project containing a number of different telescope pointings may well require weeks or months for completion.

Scheduling of observations is a two-step process that attempts to construct an optimized schedule, i.e., one that will accomplish as many of the pool of accepted observations as possible. The first step of the process consists of identifying for each observation its best weeks of the year, taking into account solar constraints, guide-star availability, orbital

target visibility, and South Atlantic Anomaly (SAA) impact, along with any constraints stated in the proposal. The second step of the process is performed in the four weeks before the observations occur, and consists of ordering the observations optimally within each week, taking into account the detailed commanding, telemetry, and orbital constraints. Consultations with the GOs will occur frequently during these planning activities.

### 7.3 Scheduling Priorities

The TAC and the STScI Director will place the highest-ranked GO observing programs into the "accepted" scheduling pool. In addition, a smaller group of highly ranked proposals will be placed in a "supplemental" pool. The supplemental programs will be inactive, in the sense that they will proceed to Phase II only in case of a serious contingency (such as failure of one of the *HST* instruments). The sizes of the Cycle 5 accepted and supplemental pools will be determined near the time of the peer-review meetings, based on the best estimate of the available Cycle 5 observing time.

Successful proposers should be aware that the actual execution of their observations may, in some cases, prove impossible. Possible reasons include the following: (1) the accepted observation could be found technically extremely difficult or infeasible only after receipt of the Phase II information; (2) it might be found that suitable guide stars do not exist; or (3) the total amount of *HST* observing time actually available could prove to be less than assumed. Therefore, *all observations are accepted for the HST program with the understanding that there can be no guarantee that the observations will actually be obtained.* Target-of-opportunity and parallel programs are particularly complex to plan and execute, and will be completed only to the extent that circumstances allow.

GOs will be informed of the priority pool into which their observations have been placed in the Phase I notification letter from the Director.

### 7.4 Execution of Observations

For most observations *HST* operates in a preplanned fashion through commands stored in its onboard computers. Execution of any real-time interactions (see §§4.1.3 and 15) is carried out by STScI Operations Astronomers (OAs) and Science Operations Specialists (SOSs). For real-time interactions, GOs are expected to be present at STScI to participate in the decisions to be implemented via the real-time commands. They will be assisted by the OAs and SOSs.

### 7.5 Data Rights

GOs and GTOs have exclusive access to their scientific data during a proprietary period. Normally this period is the 12 months following the date on which the data are archived and made available to the investigator after routine data processing (§8.1). At the end of the proprietary period, data are available for analysis by any interested scientist through the *HST* archive (see §§3.3 and 9).

Proprietary periods longer than 12 months may occasionally be appropriate for long-term programs (defined in §3.1.3 as programs whose observations extend over more than one scheduling period) if there is a need to have most or all of the data available before any significant scientific results can be obtained. Other special circumstances requiring extensions of the proprietary periods may also arise for GO programs of any scope. NASA policy permits the STScI Director to lengthen the proprietary period by up to an additional 12 months,

in cases where the Director concludes that such an extension is justified. *Requests for data-rights extensions beyond 12 months should be made in the original observing proposal*, and will be subject to TAC review.

Proposers who wish to request a proprietary period shorter than one year, or to waive their proprietary rights, are welcome to so specify in their proposals. Because of the potential benefit to the community at large, particularly in the case of large projects, proposers are asked to give this possibility serious consideration whenever they feel that such waivers would not be harmful to their programs.

It should be noted that certain information about observations, including for example data-quality assessments and count rates, will be collected when observations are made and will be included in the archival database. Such information is not considered proprietary.

## 7.6 Publication of HST Results

It is expected that the results of *HST* observations and archival research will be published in the scientific literature. All publications based on *HST* data must carry the following footnote (with the phrase in brackets included in the case of archival research):

"Based on observations made with the NASA/ESA *Hubble Space Telescope*, obtained [from the data archive] at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555."

If the research was supported by a grant from STScI, the publication should also carry the following acknowledgment at the end of the text:

"Support for this work was provided by NASA through grant number \_\_\_\_\_ from the Space Telescope Science Institute, which is operated by AURA, Inc., under NASA contract NAS 5-26555."

One preprint or reprint of each refereed publication based on *HST* research must be sent to the following address:

Librarian  
Space Telescope Science Institute  
3700 San Martin Dr.  
Baltimore, MD 21218 USA

In addition, one *preprint* of each publication based on *HST* research should be sent to the following address:

Dr. David Leckrone  
*HST* Senior Scientist  
Code 440  
Goddard Space Flight Center  
Greenbelt, MD 20771 USA

This advance information is important for planning and evaluation of the scientific operation of the *HST* mission.

## 8. Data Processing and Analysis

This section briefly describes the routine processing applied to all *HST* data and the data products that observers will receive. It also outlines some of the tools that STScI provides to assist GOs with analysis of their data.

## 8.1 Routine Scientific Data Processing

Scientific data are routed from *HST* to the Tracking and Data Relay Satellite System (TDRSS), through the TDRSS ground station at White Sands, New Mexico, to the Data Capture Facility at Goddard Space Flight Center in Greenbelt, Maryland, and finally to STScI. The Routine Scientific Data Processing (RSDP) system (also known as the "pipeline") passes these data through standard edit, calibration, and data-product-generation processing. These functions, performed automatically, include the following:

- Reformat and edit data from spacecraft packet format to images
- Perform standard calibrations (flat fields, wavelength calibrations, background subtraction, etc.)
- Produce standard data output products (FITS tapes of raw and calibrated images, black-and-white photographic representations, standard plots, etc.)

One tape copy (usually Exabyte or 9-track magnetic tape) of the raw and processed data is made and sent to the PI or his/her designee. Any further processing or scientific analysis is the responsibility of the GO. The raw and calibrated data are also stored in the Hubble Data Archive, where they become available to other researchers after expiration of the data-rights period.

As described below, STScI provides assistance with data analysis and archive access, either by e-mail or telephone, or during GO visits to Baltimore.

## 8.2 Space Telescope Science Data Analysis System

The Space Telescope Science Data Analysis System (STSDAS) is a set of tools and support software used to calibrate and analyze *HST* data. A companion package, TABLES, is a set of tools for creating and manipulating tabular data, reading and writing FITS images and tables, and creating customized graphics. STSDAS and TABLES are layered onto the Image Reduction and Analysis Facility (IRAF) software from the National Optical Astronomy Observatories (NOAO); one must be running IRAF in order to run STSDAS and TABLES.

STSDAS and TABLES are portable and, because they are layered onto IRAF, should run on any system for which an IRAF port exists. STScI, in conjunction with NOAO, actively supports STSDAS and TABLES on VAX systems running VMS (including VAXstations), DECstations running Ultrix, Sun workstations and file servers running Sun/OS 4.1.3, and HP and SGI workstations. Ports to Sun/Solaris and to the DEC/Alpha running OSF-1 and OpenVMS are under development. *HST* observers may use both STSDAS and IRAF applications for their data reduction and analysis.

STSDAS and TABLES provide a large range of data-analysis tools, including the following:

- Calibration of *HST* data
- Synthetic photometry
- *HST* throughput modelling and exposure-time estimation
- Interactive curve fitting and surface photometry
- Image restoration
- Fourier analysis
- Non-parametric statistical analysis
- Table creation and manipulation

- FITS image and table I/O
- Graphics tasks tailored to *HST* data

The STSDAS calibration software is the same as used in the RSDP. *HST* observers can, therefore, recalibrate their data, examine intermediate calibration steps, and re-run the pipeline using different calibration switch settings and reference data. STSDAS includes the software needed to generate new versions of calibration reference data and calibration parameters. STSDAS also provides tools for on-site users to access the Calibration Data Base and the data archive.

The current release of STSDAS (version 1.3.2) is available for downloading from STEIS (see §2.4), or it may be obtained on magnetic tape through a request to [sdas@stsci.edu](mailto:sdas@stsci.edu). Further information is contained in the *STSDAS User's Guide*, available from the USB as described in §2.2. Questions about STSDAS may be addressed to [hotseat@stsci.edu](mailto:hotseat@stsci.edu) or to the telephone number listed in Appendix A1.

### 8.3 Data Analysis Support

A comprehensive guide to *HST* data products and data analysis, the *HST Data Handbook*, is available (see §2.2).

In addition, STScI maintains a staff of Science Data Analysts (SDAs) who can assist GOs with all phases of their data analysis. SDAs can provide up-to-date instrument and data-analysis information and can answer GO questions not addressed in the *HST Data Handbook*. Data-analysis questions may be referred to the "analysis" hotseat ([analysis@stsci.edu](mailto:analysis@stsci.edu) or 410-338-1082).

It is strongly recommended that new GOs (and experienced GOs who may be confronting complicated new data-analysis issues) plan at least one 1-2 week post-observation visit to STScI for the purpose of learning how to work with their data.

## 9. Facilities for Archival Research

Policies for submitting requests for archival *HST* data, and for proposing funded Archival Research (AR), were discussed in §3.3. The following subsections give an overview of the archive facilities available at STScI and methods for accessing them. Further information is given in the *HST Archive Primer* and in more detail in the *HST Archive Manual*, both of which are part of the *HST* documentation described in §2.2.

All science and calibration data, along with a large fraction of the engineering data, are placed in the Hubble Data Archive. As of March 1994, the archive contained approximately 1 Tbyte of data, comprising 350,351 individual datasets. About 1 Gbyte of new data is archived each day. Over half of the archive (about 560 Gbytes) is science data, with 108,729 datasets covering 5,178 different targets.

Most of the data in the archive are public and may be retrieved by any user. The public data in the archive currently comprise 15,845 WF/PC images (including 8,844 calibration frames), 4,713 FOC images (1,087 calibration); 13,874 FOS spectra (5,503 calibration), 12,637 GHRS spectra (4,996 calibration), and 5,341 HSP scans (1,608 calibration). There is also a small amount of public data obtained after the servicing mission, including WFPC2 data, which are primarily some of the Early Release Observations along with calibration data.

## 9.1 Hubble Data Archive and StarView

The Hubble Data Archive is the hardware and software system in which *HST* data are stored. In the past, the heart of the archive was a system known as the Data Management Facility (DMF). A transition of archive engines is currently underway. The new archive engine, the Data Archive and Distribution Service (DADS), has been used to archive all the data from *HST* obtained since the servicing mission at the end of 1993, and older data are currently in the process of being copied from DMF to DADS. No interruption of service is anticipated, although users will need to be aware of the transition. Completion of the transition is scheduled for the autumn of 1994.

STScI maintains Sun (stdatu.stsci.edu) and VMS (stdata.stsci.edu) host machines for users who want to work with the archive. Users should telnet to either computer and log in as **guest** with a password of **archive**. Guest users are able to browse the archive catalog and preview public data using the software interface StarView, and retrieve documentation about the archive. Guest users cannot retrieve data from the archive, but they may use the guest account to become registered users by issuing the command **register** at the command line on either computer.

Registered users are assigned archive accounts, which allow them to retrieve data from the archive using a set of software called "StarView." The *Archive Primer*, which may be obtained as described in §2.2 (or is also available in electronic form), contains details of how to run either the CRT or X-version of StarView, though most users should be able to get started just from the hints they will get when they log onto one of the host machines. Users logging in from a workstation with an X-terminal will most likely want to use "xstarview," because it allows one to preview the data before deciding whether to retrieve it. Both the CRT and X-versions of StarView allow one to search for *HST* observations based on any SIMBAD-recognized target name.

For those who want a simpler way to find out what is in the *HST* archive, an alternative to StarView is the Archived Exposures Catalog (AEC). This is a flat ASCII file that can be downloaded from STEIS, or from the stdatu or stdata computers. The AEC contains summary information about exposures, including the target name, position, instrument mode, and the date on which the data became (or will become) public. The AEC is updated monthly. An advantage of the AEC is that it is a text file that may be examined with any text editor. The advantage of StarView, on the other hand, is that it provides more detailed information about observations, allows one to search for many observations simultaneously using selected keyword criteria, and allows one to preview public *HST* images and spectra.

STScI maintains an "archive hotseat" (archive@stsci.edu or 410-338-4547) which operates during normal office hours. Any archive-related problems should be referred to the hotseat.

## 9.2 Archival Data Analysis

Several mechanisms are provided for Archival Researchers (ARs) to retrieve data. By logging into the stdatu or stdata computers and using StarView, registered users can retrieve up to 500 Megabytes of archival data. (While the DMF is still operating, one retrieves the data to one of the archive host machines, and then uses ftp to transfer the data to one's home machine. The new archive system, DADS, will be able to ship the data directly to the home computer.)

Network bandwidth limitations will limit the amount of data that realistically can be transferred electronically. ARs may submit requests for large amounts of public *HST* data to be written to Exabyte or 9-track tape and shipped to them. Such requests may be submitted using StarView, or alternatively by completing the "Request for Archival Data" form, which is maintained as a PostScript file on the archive host machines. (The form can also be obtained by sending e-mail to the archive hotseat.) Requests for up to 20 Gbytes of data for unfunded researchers will be accepted. Larger amounts will be provided to funded ARs, as outlined in their proposals.

STScI can provide limited assistance in the reduction and analysis of archival data, and encourages ARs to visit the Institute. In particular, the archive hotseat will attempt to resolve any problems encountered in using StarView, and can provide advice on strategies for conducting searches of the archive. However, proposers should plan to conduct the bulk of their archival research at their home institutions, and should request funding accordingly. Limited resources preclude extensive assistance in the reduction and analysis of data obtained by non-funded ARs.



## PART II: THE HUBBLE SPACE TELESCOPE

### 10. System Overview

#### 10.1 Telescope Description

As shown in Fig. 1, *HST*'s Scientific Instruments (SIs) are mounted in bays behind the primary mirror. The Wide Field Planetary Camera 2 occupies one of the radial bays, with an attached  $45^\circ$  pickoff mirror that allows it to receive the on-axis beam. Three SIs (Faint Object Camera, Faint Object Spectrograph, and Goddard High Resolution Spectrograph) are mounted in the axial bays and receive images several arcminutes off-axis.

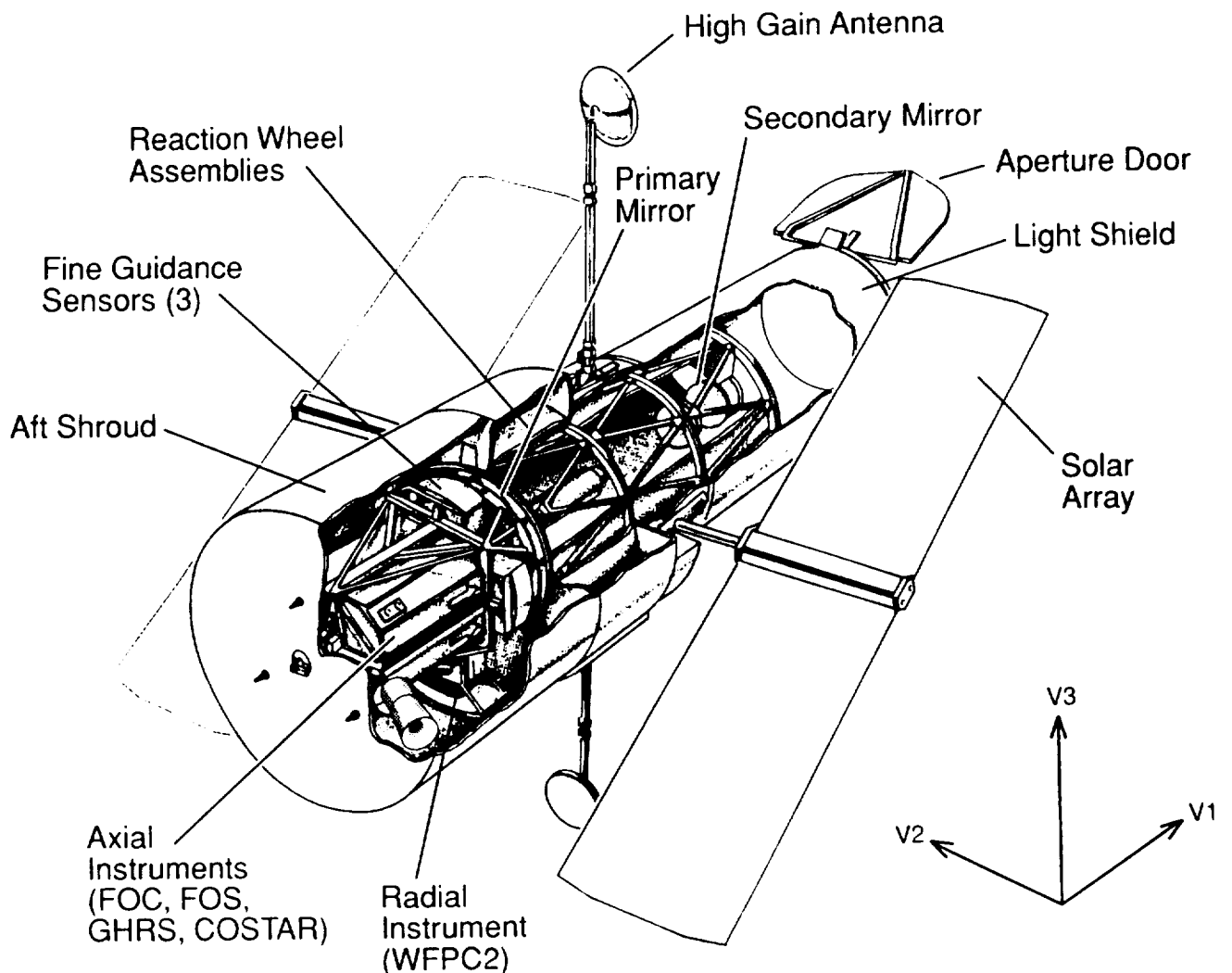


Figure 1

*The Hubble Space Telescope*

Major components are labelled, and definitions of V1, V2, V3 spacecraft axes are indicated

During the servicing mission in December 1993, the astronauts installed the Corrective Optics Space Telescope Axial Replacement (COSTAR) in the fourth axial bay (in place of the High Speed Photometer). COSTAR deployed corrective reflecting optics in the optical paths in front of the Faint Object Camera, Faint Object Spectrograph, and Goddard High Resolution Spectrograph, thus removing the effects of the primary mirror's spherical aberration. In addition the Wide Field and Planetary Camera (WF/PC) was replaced by the WFPC2, which contains internal optics to correct the spherical aberration.

The Fine Guidance Sensors (FGSs) occupy the other three radial bays and receive light 10–14 arcminutes off-axis. Since at most two FGSs are required to guide the telescope, it is possible to conduct astrometric observations with a third FGS. Their performance is unaffected by the installation of COSTAR.

For an overview of the SIs, see §12. Detailed information about each SI is contained in separate *Instrument Handbooks* (see §2.2).

*HST* receives electrical power from two solar arrays (see Fig. 1), which are turned (and the spacecraft rolled about its optical axis) so that the panels face the incident sunlight. During the 1993 servicing mission the astronauts installed new solar arrays, which will significantly reduce the thermally induced vibrations that the old arrays had been producing. Nickel-hydrogen batteries provide power during orbital night. The two high-gain antennas shown in Fig. 1 provide communications with the ground (via the Tracking and Data Relay Satellite System). Power, control, and communications functions are carried out by the Support Systems Module (SSM), which encircles the primary mirror.

## 10.2 *HST* Maneuvering and Pointing

*HST* is, in principle, free to roll about its optical axis. However, this freedom is limited by the need to keep sunlight shining on the solar arrays, and by a thermal design that assumes that the Sun always heats the same side of the telescope.

To discuss *HST* pointing, it is useful to define a coordinate system that is fixed to the telescope. This system consists of three orthogonal axes: V1, V2, and V3. V1 lies along the optical axis, V2 is parallel to the solar-array rotation axis, and V3 is perpendicular to the solar-array axis (see Fig. 1). Power and thermal constraints are satisfied when the telescope is oriented such that the Sun is in the half-plane defined by the  $\pm V1$  axis and the positive V3 axis. The roll angle that optimizes the solar-array positioning with respect to the Sun is called the “nominal roll.”

It should be noted that the nominal roll angle required for a particular observation depends on the location of the target and *the date of the observation*. Observations of the same target made at different times will, in general, be made at different roll angles. Instructions for calculating the nominal roll angle for a given target on a given date are available from the User Support Branch.

Some departures from nominal roll are permitted during *HST* observing (e.g., if a specific roll is required at a specific date, or if the same roll is required for observations made at different times). Observers whose programs may require off-nominal rolls should contact the USB for further information.

*HST* utilizes electrically driven reaction wheels to perform all maneuvering required for guide-star acquisition and pointing control. A separate set of rate gyroscopes is used to provide attitude information to the pointing control system. The servicing mission restored or replaced three gyros that had failed since the original launch, so that the spacecraft

currently has a total of six operational gyros. Any three of these are the minimum required for telescope pointing control.

The slew rate is limited to approximately  $6^\circ$  per minute of time. Thus, about one hour is needed to go full circle in pitch, yaw, or roll. Upon arrival at a new target, up to 12 additional minutes must be allowed for the FGSs to acquire a new pair of guide stars. As a result, large maneuvers are costly in time and are generally scheduled for periods of Earth occultation or crossing of the South Atlantic Anomaly (see §13.2).

The telescope does not observe targets within  $50^\circ$  of the Sun,  $15^\circ 5'$  of any illuminated portion of the Earth,  $7^\circ 6'$  of the dark limb of the Earth, nor  $9^\circ$  of the Moon. Following the servicing mission, the telescope is again allowed to point directly away from the Sun.

There are exceptions to these rules for *HST* pointing in certain cases. For instance, the bright Earth is a useful flat-field calibration source. However, there are onboard safety features that cannot be overridden. The most important of these is that the aperture door shown in Fig. 1 will close automatically whenever *HST* is pointed within  $20^\circ$  of the Sun, in order to prevent direct sunlight from reaching the optics and focal plane.

Objects in the inner solar system, such as Venus or comets near perihelion, are unfortunately difficult or impossible to observe with *HST*, because of the  $50^\circ$  solar limit. When the scientific justification is compelling, observations of Venus and time-critical observations of other solar-system objects lying between approximately  $45^\circ$  and  $50^\circ$  of the Sun may be possible, but difficult.

### 10.3 Data Storage and Transmission

The *HST* observing schedule is constructed at STScI (see §7.2) and forwarded to the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. The *HST* is controlled from the Space Telescope Operations Control Center (STOCC), located at GSFC. Communication with the spacecraft is via the Tracking and Data Relay Satellite System (TDRSS), which consists of a set of satellites in geosynchronous orbit.

Commands to *HST* originate at the STOCC and are sent via land-line or communications satellites to the TDRSS ground station at White Sands. From there the commands are sent via the appropriate TDRS to *HST*. Scientific data are sent from *HST* to the STOCC via the reverse path, and then from the STOCC to the STScI via dedicated high-speed links.

The TDRSS network supports many spacecraft in addition to *HST*. Therefore, use of the network, either to send commands or return data, must be scheduled weeks in advance. Because of limited TDRSS availability, command sequences for *HST* observations are normally uplinked periodically and stored in the onboard computers. *HST* then executes the observations automatically.

It is possible for observers at STScI to interact in real time with *HST* for specific purposes, such as certain target acquisitions. In practice, because of TDRSS scheduling difficulties and other constraints, fewer than 200 real-time observations are requested per year. See §15 for further discussion.

*HST* uses two onboard tape recorders to store scientific data. Except when real-time access is required, most *HST* observations are stored on tape and read back to the ground several hours later. Each tape recorder can store up to 15 full WFPC2 frames. Programs requiring more than 15 full frames per *HST* orbit will exceed this capacity and may be difficult or impossible to schedule.

There are also limits to the amount of data that can be handled by the ground system supporting *HST*. Some scientific programs requiring very high data-acquisition rates cannot be accommodated, because the SIs would generate more data than either the links or ground system could handle.

## 11. Telescope Performance

### 11.1 Optical Performance

Because the primary mirror has about one-half wave of spherical aberration, the Optical Telescope Assembly (OTA) did not achieve its design performance until after the December 1993 servicing mission. Table 2 gives a summary of the excellent optical performance now being achieved.

**Table 2**  
**HST Optical Characteristics and Performance**

Aperture	2.4 m
Wavelength coverage (MgF <sub>2</sub> -overcoated aluminum)	1100 Å to 1 mm
Focal ratio (without COSTAR)	<i>f</i> /24
Plate scale (on axis, without COSTAR)	3.58 arcsec mm <sup>-1</sup>
FWHM of WFPC2 images (at 6328 Å)	0.053 arcsec
WFPC2 encircled energy within 0".1 radius (at 6328 Å)	55–65%
FWHM of FOC images (at 4860 Å)	0.042 arcsec
FOC encircled energy within 0".1 radius (at 4860 Å)	86%

Software has been developed at STScI for detailed simulations of *HST* images, which agree very well with actually observed (pre- and post-repair) images. This Telescope Image Modelling (TIM) software, with its point-spread-function (PSF) library, is available for downloading from STEIS. Another set of software specifically designed to simulate *HST* camera images, called TINYTIM, is also available.

Fig. 2 shows actual measurements of the PSF and encircled energy achieved with the Faint Object Camera, following COSTAR installation.

### 11.2 Guiding Performance

*HST*'s Pointing Control System (PCS) has two principal hardware components. Rate gyros are the guidance sensors for large maneuvers and high-frequency (> 1 Hz) pointing control. At lower frequencies, the optical Fine Guidance Sensors (FGSs) provide for pointing stability, as well as for precision maneuvers such as moving-target tracking and offsets and spatial scans.

Each of the three FGSs covers a 90° sector in the outer portion of the *HST* field of view (FOV), as shown in Fig. 3 in §12.7. Optics within the FGS, using precision motor-encoder combinations, select a 5" × 5" region of sky into an *x, y* interferometer system. Once an FGS is locked onto a star, the motor-encoders are driven to track the guide star. The encoder positions are used by the PCS software to update the current telescope attitude and correct the pointing.

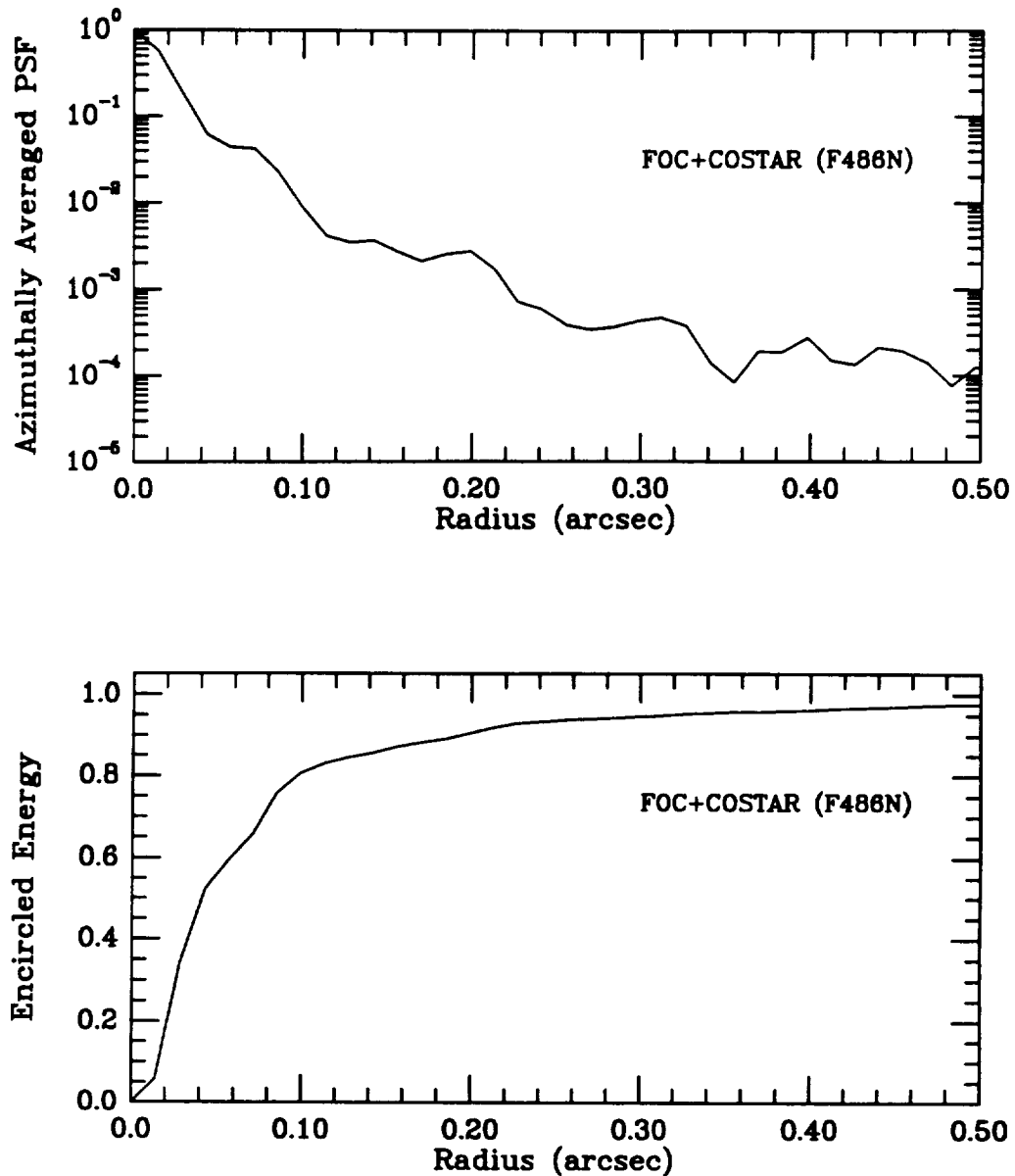


Figure 2  
Measurements of the point-spread function (*top*) and encircled energy (*bottom*)  
achieved with the FOC at 4860 Å after COSTAR installation.

The FGSs have two guiding modes: Fine Lock and Coarse Track. Fine Lock was designed to keep telescope jitter below  $0''.007$  rms. In-orbit performance in Fine Lock has actually proven to be slightly better than planned during "quiet" periods of the orbit ( $0''.005$  rms,  $0''.009$  FWHM). However, at this writing, larger jitter (about  $0''.020$ – $0''.040$  rms, with periods of 2–10 seconds) is still occurring during 2- to 5-minute intervals as *HST* passes from day to night, or night to day. This additional jitter is attributed to thermal effects as the solar arrays and the spacecraft itself are heated or cooled. This jitter is expected to be

substantially reduced after onboard software is retuned for the newly installed solar arrays (currently planned for September 1994).

Coarse Track is now believed to cause degradation in mechanical bearings in the FGSs, and accordingly is no longer available as a guiding mode.

Guide-star acquisition times are typically 12 minutes. Reacquisitions following interruptions due to Earth occultations take about 6 minutes.

It is also possible to take WFPC2 exposures (primarily "snapshot" exposures) without guide stars, using only gyro pointing control. The rms absolute pointing accuracy using gyros is about  $14''$ , and the pointing drifts at a rate of  $1.4 \pm 0.7 \text{ mas s}^{-1}$ .

### 11.3 Observing and Program Efficiencies

*HST*'s "observing efficiency" may be defined as the fraction of the total time that is devoted to acquiring guide stars, acquiring astronomical targets, and exposing on them. In other words, the observing efficiency is defined as the ratio of "spacecraft time" to total time.

The main factors that limit the observing efficiency are (1) the low spacecraft orbit, with attendant frequent Earth occultation of most targets; (2) interruptions by passages through the South Atlantic Anomaly; (3) the relatively slow slew rate; (4) telemetry constraints; and (5) the performance of the scheduling algorithm.

During Cycle 5, it is anticipated that the observing efficiency will be about 45%. About 80% of the spacecraft time is allocated to scientific observations, with the remainder devoted to calibration observations (10%), engineering (5%), and repeats of failed observations (5%). Because of the allocation of about 25% of the scientific observing time to GTOs (see §3.5), the time available to GOs during Cycle 5 will be about 270 orbits per month, or approximately 3240 orbits during the entire 12-month cycle.

The procedure for estimating (and minimizing) the number of spacecraft orbits required for a given set of exposures is provided in the *Phase I Proposal Instructions*. In addition to the on-target exposure time, the procedure takes into account target visibility durations, time required for guide-star acquisitions and reacquisitions and for target acquisitions, and instrument overheads and readout times.

Although scientific merit is the primary criterion in the evaluation of proposals (as discussed in §6.2.3), the TAC will also consider the efficiency with which *HST* observing time is used by each program.

## 12. Scientific Instrument Overview

The following Scientific Instruments (SIs) will be available on *HST* during Cycle 5:

- Wide Field Planetary Camera 2 (WFPC2)
- Faint Object Camera (FOC) (*f*/96 only)
- Faint Object Spectrograph (FOS)
- Goddard High Resolution Spectrograph (GHRS)
- Fine Guidance Sensors (FGS)

All of the SIs are permanently mounted at the *HST* focal plane, so that all except the WFPC2 receive light that is slightly off-axis. A schematic diagram of the telescope focal plane is given below (Fig. 3 in §12.7).

Tables 3(a)-(e) provide a summary of the capabilities of the SIs. For some applications, more than one instrument can accomplish a given task, but not necessarily with equal quality or speed.

The following subsections contain brief descriptions of the five SIs. After examining Tables 3(a)-(e), prospective proposers should read these descriptions in order to determine which SIs are likely to be most suitable for their programs. Revised and updated *Instrument Handbooks*, which discuss the SIs in detail, have been distributed to institutional libraries, and are available from STScI as described in §2.2. The appropriate *Handbooks* must be consulted before actual preparation of observing proposals. In addition, exposure simulators are available for the SIs to assist in the estimation of exposure times, as described in the *Synphot User's Guide*; users may contact USB for more information.

Data from the following two SIs, which were removed from *HST* during the December 1993 servicing mission, are now available only in archival form:

- Wide Field and Planetary Camera (WF/PC)
- High Speed Photometer (HSP)

Overviews of the capabilities of these two instruments are provided in Appendix A3, which should be consulted by persons interested in proposing Archival Research with WF/PC and/or HSP data. Archival data from the FOC, FOS, GHRS, and FGS are, of course, also available.

### 12.1 Wide Field Planetary Camera 2 (WFPC2)

The WFPC2, which is *HST*'s only on-axis instrument, is designed to provide digital imaging over a wide field of view (FOV). It has three "wide-field" charge-coupled devices (CCDs), and one high-resolution (or "planetary") CCD. Each CCD covers  $800 \times 800$  pixels and is sensitive from 1200 to 11,000 Å. All four CCDs are exposed simultaneously, with the target of interest being placed as desired within the FOV.

The three Wide Field Camera (WFC) CCDs are arranged in an "L"-shaped FOV whose long side projects to  $2'5$ , with a projected pixel size of  $0''.10$ . The Planetary Camera (PC) CCD has a FOV of  $35'' \times 35''$ , and a projected pixel size of  $0''.046$ . A variety of filters may be inserted into the optical path. Polarimetry may be performed by placing a polarizer into the beam. A ramp filter exists that effectively allows one to image a small ( $\lesssim 10''$ ) object in an arbitrary 1–3% bandpass at any wavelength between 3700 and 9800 Å, by appropriately positioning the target within the FOV.

The WFC configuration provides the largest FOV available on *HST*, but undersamples the cores of stellar images; the PC configuration samples the images better, over its smaller FOV.

### 12.2 Faint Object Camera (FOC)

The FOC is intended to provide high-resolution images of small fields. The camera reimages the *HST* focal plane to provide two different scales. The focal ratios were originally  $f/96$  and  $f/48$ ; to avoid confusion these names are retained, but installation of COSTAR changed the effective focal ratios to  $f/151$  and  $f/75$ , respectively. A variety of filters, prisms (for slitless spectroscopy), and polarizers may be placed in the optical beam.

The  $f/96$  camera (plus COSTAR) has a FOV of  $7'' \times 7''$  and a pixel size of  $0''.014 \times 0''.014$  in its standard  $512 \times 512$  format; a field of  $14'' \times 14''$  can be used with the  $512 \times 1024$  pixel format with a (rectangular) pixel size of  $0''.028 \times 0''.014$ . This camera provides two

**Table 3**  
**HST Instrument Capabilities**

**(a) Direct Imaging<sup>(1)</sup>**

Instrument	Field of View	Projected Pixel Spacing on Sky	Wavelength Range (Å)	Magnitude Limit <sup>(2)</sup>
WFPC2 <sup>(3)</sup>	154" × 154"	0"10	1200-11,000	28.0
	35" × 35"	0"046	1200-11,000	27.7
FOC <i>f</i> /96 <sup>(4)</sup>	14" × 14"	0"014	1150-6500	26

**(b) Slit Spectroscopy**

Instrument	Projected Aperture Size	Resolving Power ( $\lambda/\Delta\lambda$ )	Time Resolution	Wavelength Range (Å)	Magnitude Limit <sup>(2)</sup>
FOS <sup>(5)</sup>	0"085-3"7	1300	30 ms	1150-8500	13.7-20.5-20.2
		250	30 ms	1150-8500	15.3-22.9-21.5
GHRS (Side 1)	0"22, 1"74	80,000	50 ms	1150-1700	11-14
		25,000	50 ms	1100-1900	13-16
		2,000	50 ms	1100-1900	17
		80,000	50 ms	1700-3200	11-14
		25,000	50 ms	1150-3200	13-16
(Side 2)					

**(c) Slitless Spectroscopy<sup>(8)</sup>**

Instrument	Projected Pixel Spacing on Sky	Resolving Power ( $\lambda/\Delta\lambda$ )	Wavelength Range (Å)	Magnitude Limit
WFPC2 <sup>(6)</sup>	0"1	~100	3700-9800	25
FOC <i>f</i> /96	0"014	50 at 1500 Å	1150-6000	22

**(d) Positional Astrometry**

Instrument	Field of View	Positional Accuracy	Wavelength Range (Å)	Magnitude Limit <sup>(7)</sup>
FGS	69 arcmin <sup>2</sup>	±0"002	4700-7100	17



Table 3 (continued)  
HST Instrument Capabilities  
(e) Double-Star Astrometry

Instrument	Separation Accuracy	Wavelength Range (Å)	Magnitude Limit <sup>(8)</sup>
FGS	$\pm 0''.005$	4700-7100	14

Notes to Tables 3(a)-(e):

1. Both cameras have polarimetric imaging capabilities. The FOC has a coronagraphic capability.

2. Predicted limiting  $V$  magnitude for an unreddened A0 V star in order to achieve a S/N ratio of 5 in an exposure time of 1 hour. Single entries refer to wavelengths near the center of the indicated wavelength range. For FOC direct imaging, the F342W filter was assumed. When two values are given, the first refers to wavelengths near the short-wavelength limit, and the second to those near the long-wavelength limit. For FOS spectroscopy, three values are given, corresponding to 1300, 3200, and 6000 Å, respectively.

3. The WFPC2 has four CCD chips that are exposed simultaneously. Three are "wide-field" chips, each covering a  $77'' \times 77''$  field and arranged in an "L" shape, and the fourth is a "planetary" chip covering a  $35'' \times 35''$  field.

4. The available FOC configuration is referred to by its original  $f$ -ratio,  $f/96$ . With COSTAR the effective focal ratio is  $f/151$ . The  $f/288$  configuration is no longer supported. Use of the  $f/48$  configuration is suspended due to failures to attain high-voltage turnon.

5. The FOS can also perform spectropolarimetry, but the utility of this mode after installation of COSTAR is in question.

6. Slitless spectroscopy can be done using the FOC's "objective" prisms. WFPC2 has a capability of obtaining low-resolution "spectra" by placing a target successively at various locations in the WFPC2 ramp filter.

7. For  $S/N = 1$  in Fine Lock.

8. Magnitude limit for primary star.

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occulting fingers ( $0''.3$  and  $0''.5$  wide) at the entrance aperture. The  $f/96$  camera also has three polarization analyzers for polarimetric imaging.

Usage of the  $f/48$  camera is currently suspended, due to multiple failures to maintain an operational high-voltage level. This camera should not be requested in Cycle 5 proposals.

The FOC detector is a three-stage image intensifier, optically coupled to a television tube. Software centroids the individual photons. A variety of options is available for the size and shape of the area that is scanned and the spatial resolution. The dynamic range and limiting magnitude of the FOC depend on the readout format and the desired signal-to-noise ratio, but the limiting magnitude in a broad bandpass is about  $m_V = 27$ .

In comparing the FOC and WFPC2, proposers should note the following: (1) the FOC provides the higher angular resolution at all wavelengths, and the WFPC2 provides the larger field of view; (2) the FOC is faster below about 4500 Å, while the WFPC2 is faster above 4500 Å.

### 12.3 Faint Object Spectrograph (FOS)

The FOS performs low-resolution ( $R \simeq 250$  and  $1300$ ) spectroscopy of faint sources in the wavelength range  $1150$  to  $8500 \text{ \AA}$ . A variety of apertures of different sizes and shapes is available to optimize the throughput and spatial or spectral resolution. Linear and circular spectropolarimetry are also available, but the utility of these modes after installation of COSTAR may be severely limited by the multiple reflections.

In the  $R = 250$  mode the dispersers are two gratings and a prism, while six gratings are available in the  $R = 1300$  mode to cover the full wavelength range. The detectors are two 512-element Digicons, one operating from  $1150$  to  $5500 \text{ \AA}$  ("blue"), and the other from  $1620$  to  $8500 \text{ \AA}$  ("red").

The FOS can acquire data in accumulation, rapid-readout, and periodic modes. Time resolution as short as  $30 \text{ ms}$  can be achieved. The electron image is magnetically stepped through a programmed pattern during the observations, in order to provide for oversampling, compensation of sensitivity variations along the Digicon array, sky measurements, and/or measurement of orthogonally polarized images. Normally the data are read out at intervals that are short compared to the exposure time.

Following installation of COSTAR, the FOS reaches the following approximate visual magnitudes with  $S/N = 5$  in one hour:  $20.5$  at "high" resolution, and  $22.9$  with the low-resolution prism.

### 12.4 Goddard High Resolution Spectrograph (GHRS)

The GHRS is used for spectroscopy at resolving powers of  $R = 2,000$  ( $1100$ – $1900 \text{ \AA}$ ),  $25,000$  ( $1150$ – $3200 \text{ \AA}$ ), and  $80,000$  ( $1150$ – $3200 \text{ \AA}$ ). Two entrance apertures are available, which (after COSTAR installation) are  $0''.22$  square and  $1''.74$  square projected onto the sky. There are four gratings used at low and medium resolution, and echelles combined with cross dispersers for the high-resolution modes, as well as one low-dispersion grating for the  $1100$ – $1900 \text{ \AA}$  range. The detectors are 500-element Digicons which are sensitive from  $1100$  to  $1900 \text{ \AA}$  and  $1150$  to  $3300 \text{ \AA}$ , respectively. The wavelength coverage per exposure ranges from  $9 \text{ \AA}$  at the highest resolution and shortest wavelengths to as much as  $48 \text{ \AA}$  at the medium-resolution wavelengths, and  $285 \text{ \AA}$  for the low-resolution grating.

The GHRS acquires data in either an accumulation or a rapid-readout mode. In the accumulation mode, the electron image is magnetically stepped through a programmed pattern to allow for oversampling, compensation of sensitivity variations along the Digicon array, and instrumental background measurements. Doppler compensation for the orbital motion of *HST* is automatically applied. None of these functions is available in the rapid-readout mode, but time-resolved spectra may be obtained with integration times as short as  $50 \text{ ms}$ .

The GHRS can attain  $S/N = 10$  at  $1200$ – $1500 \text{ \AA}$  in  $1000 \text{ s}$ , for lightly reddened  $B0 \text{ V}$  stars of visual magnitude  $16$  in the medium-resolution configuration.

The GHRS Side 1 detector was unavailable in Cycles 2 and 3 due to an electronics failure. Side 1 provides low- ( $R = 2000$ ) and high-resolution ( $R = 80,000$ ) modes for the  $1100$ – $1900 \text{ \AA}$  range. These capabilities were restored due to installation of a relay box by the astronauts during the servicing mission, and are available for Cycle 5 proposals.

### 12.5 Fine Guidance Sensors (FGS)

In normal operation, two of the FGSs are used for spacecraft attitude control. The third FGS thus has the potential of carrying out astrometric and interferometric obser-

vations, including (1) measuring the relative positions of sources to a precision of a few milliarcseconds; (2) measuring the separations and magnitude differences of binary stars; and (3) measuring stellar angular diameters. Note that the FGSs were unaffected by the installation of COSTAR.

For positional measurements, the useful magnitude range is  $m_V = 4$  to 17, and the precision is about  $\pm 2$  mas. Generally, a target star and 5 to 10 reference stars within the FOV annulus would be observed at several epochs to yield relative proper motions and parallaxes. Note that the effective FOV for parallax observations is reduced to about  $4' \times 5'$ , since for observations six months apart the telescope's roll angle will differ by  $180^\circ$  (see §10.2).

The "TRANS" mode for double-star and angular-diameter measurements is available, and considerable data-reduction and analysis software has been developed at STScI. This mode is nominally capable of measuring (1) separations down to 5 mas and magnitude differences of up to 3 mag, for double stars whose primaries are as faint as about 14th mag, and (2) angular diameters in the 5–50 mas range. Similar measurements on non-stellar objects are also possible.

## 12.6 Calibration Overview

Calibration information is required in order to interpret the raw scientific data from the SIs. Such information is obtained from laboratory measurements made before launch, internal measurements in the SI in orbit, or observations of calibration sources in the sky. A Calibration Data Base (CDB) is maintained at STScI as part of the Space Telescope Science Data Analysis Software (STSDAS), so that calibration information is readily available to observers.

As a service to *HST* users, STScI carries out calibrations of the SIs in their standard modes; therefore, most GOs do not have to request their own calibration observations. Examples of these calibration measurements are the following:

- Wavelength scales for spectroscopic modes.
- Dark signals in the SIs as functions of geomagnetic coordinates.
- Plate scales and spatial distortions of all imaging SIs.
- Spatial flat fields for the cameras.
- Spectral flat fields for the spectrographs.
- Absolute sensitivities of the SIs, via observations of standard stars, for all standard instrument modes.
- Point-spread functions.

Proposers are encouraged to contact the appropriate Instrument Scientist to discuss SI calibration, especially if they have demanding calibration requirements beyond the standard STScI levels described in the *Instrument Handbooks*. Such requirements will necessitate allocation of additional telescope time by the TAC.

Proposers should note that understanding of SI performance continues to improve during the *HST* mission; the CDB is updated periodically to reflect this. As calibration data become available, documentation will appear in the *STScI Newsletter*, in the astronomical literature, in the user-accessible CDB, on STEIS, and in the Hubble Data Archive.

Data from all standard observing modes are automatically calibrated by RSDP (see §8.1), and both raw and calibrated data are provided to GOs. GOs may recalibrate their data using STSDAS, if desired. Data taken in non-standard modes will usually not be calibrated automatically; in such cases, calibration is left to the GO.

The new *HST Data Handbook* (see §2.2) describes in detail how *HST* data are calibrated, and discusses conditions under which it might be advantageous to recalibrate and if so how to perform the recalibration.

## 12.7 The HST Field of View

### 12.7.1 FOV Diagram

Fig. 3 shows the layout of the instrument entrance apertures in the telescope focal plane. It is shown as projected onto the sky. The *Instrument Handbooks* should be consulted for details of each instrument's aperture sizes and orientations.

The figure shows the *physical* locations of the FOC, FOS, and GHRs apertures in the focal plane. Note that the *effective* locations of the apertures are those of the first mirrors ("M1") in each of the two-mirror light paths provided by COSTAR. These effective locations are shown as open circles in Fig. 3.

In order to avoid confusion with the spacecraft's V2 and V3 axes, we define two new axes in Fig. 3, U2 and U3, which are fixed in the focal plane as projected onto the sky. At nominal roll (see §10.2), the U3 axis points toward the anti-Sun.

### 12.7.2 Aperture Locations

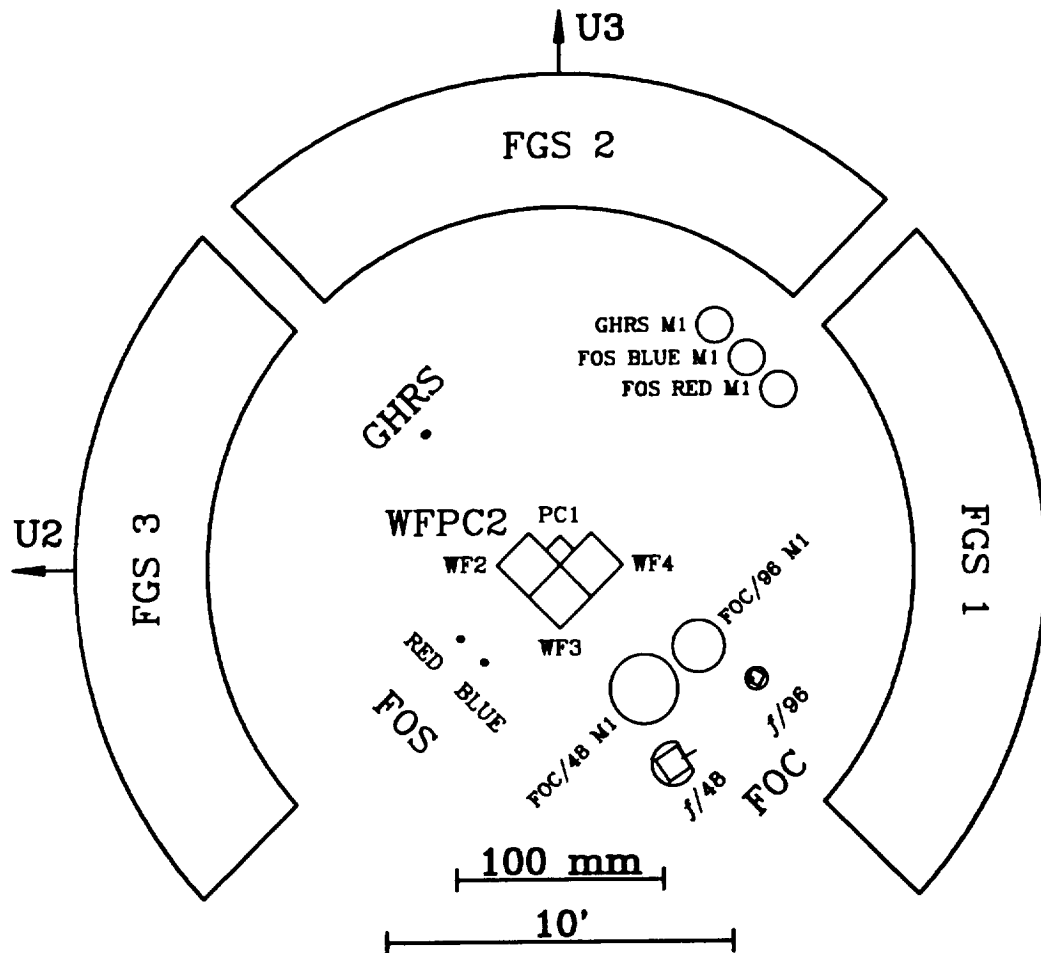
Table 4 lists the relative effective locations of the SI apertures; the U2,U3 coordinate system of Fig. 3 is used, and the linear dimensions have been converted to seconds of arc using a plate scale of  $3.58 \text{ arcsec mm}^{-1}$ . The locations are accurate to about  $\pm 1''$ .

**Table 4**  
**Nominal Effective Relative Aperture Locations**

Instrument	Aperture	U2	U3
		(arcsec)	(arcsec)
WFPC2	PC	-2	-31
	WF2	52	6
	WF3	-1	47
	WF4	-55	7
FOC	<i>f</i> /96	-242	-135
FOS	Blue	-330	358
	Red	-384	304
GHRs		-270	411
FGS	FGS-1	-726	0
	FGS-2	0	726
	FGS-3	726	0

## 12.8 Bright-Object Constraints

Several of the SIs must be protected against over-illumination; these constraints are discussed below. Observations that violate these constraints should not be proposed.



## HST Field of View (As projected onto the sky)

Figure 3

Circles labelled "M1" show the effective aperture locations for the FOC, FOS, and GHRS after COSTAR installation.

Note that there may be non-linearity, saturation, or residual-image effects that set in at substantially fainter limits than the safety limits discussed below; the *Instrument Handbooks* should be consulted for details.

1. *WFPC2*. No safety-related brightness limits.
2. *FOC*. May be damaged by continuous illumination by a star of  $V \leq 9$  anywhere in the field of view, or by an extended source with  $V$  surface brightness of  $12 \text{ mag arcsec}^{-2}$ .

3. *FOS*.  $V$ -magnitude limits of  $-2.0$  to  $12.5$ , depending on the spectral type of the star and the grating or mirror used.

4. *GHR*.  $V$ -magnitude limits to as faint as  $6$ , depending on the color of the star, apply for the unattenuated mirrors. There are no safety-related limits for the attenuated mirrors, or for the dispersing elements.

5. *FGS*. Objects as bright as  $V = 1.8$  may be observed if the 5-mag neutral-density filter is used. Observations on all objects brighter than  $V = 6.8$  should be performed with this filter.

### 13. Orbital Constraints

*HST* is in a relatively low orbit, whose nominal parameters (following the orbital boost in December 1993) are summarized in Table 5. The low orbit imposes a number of constraints upon scientific programs, which will be discussed in the following subsections.

Table 5  
HST Nominal Orbital Parameters  
(Epoch 1994.2)

Semimajor axis	6972 km
Altitude	601 km (324 naut. mi.)
Rate of descent	$1.8 \text{ km yr}^{-1}$
Inclination	$28^{\circ}5$
Nodal period	96.4 min
Orbital precession period	56.1 days

#### 13.1 Target Viewing Times and Continuous Viewing Zones

As seen from *HST*, targets in most of the sky are occulted by the Earth for varying lengths of time during each 96-min orbit. Targets lying in the orbital plane are occulted for the longest interval, about 36 min per orbit. However, this is a purely geometric limit and does not include the additional time lost due to Earth-limb avoidance limits (see §10.2), guide-star acquisition or reacquisition, instrument setup, and SAA avoidance (§13.2). These orbital occultations are analogous to the diurnal cycle for ground-based observing and impose the most serious constraint limiting the efficiency of most *HST* observations.

The length of target occultation decreases with distance from the spacecraft orbital plane (see the *Proposal Instructions* for a detailed table). Targets lying within  $24^{\circ}$  of the orbital poles are not geometrically occulted at all during the *HST* orbit. However, the size of the resulting "continuous viewing zones" (CVZs) is substantially reduced by the Earth-limb avoidance angles. Note also that scattered Earth light may be significant when *HST* observes near the bright Earth limb.

Observations of targets that lie in the CVZ have been shown to be more than a factor of two more efficient than the ensemble of non-CVZ observations; hence observers are encouraged to use the CVZ when possible, in order to maximize the scientific return and efficiency of their observations. The allocation of spacecraft orbits rather than hours, beginning in Cycle 5, allows proposers to evaluate straightforwardly the efficiency gains

realized through observations made in the CVZ. It will often be found that use of the CVZ will allow a significant increase in the exposure time possible during a given number of spacecraft orbits, and hence its exploitation is to the proposer's advantage.

Since the orbital poles lie  $28^{\circ}5'$  from the celestial poles, any target located in the two declination zones near  $\pm 61^{\circ}5'$  will be in the CVZ at some time during the 56-day *HST* precessional cycle. The maximum uninterrupted length of an observation may then be up to 7 days, although passages through the SAA (see below) will force gaps in coverage after a maximum of 14 hours.

A detailed examination of all the observing constraints has shown that substantial scheduling opportunities for CVZ observing exist in the zones  $57^{\circ} \leq |\delta| \leq 72^{\circ}$ , and limited opportunities in the  $53^{\circ}$ – $57^{\circ}$  and  $72^{\circ}$ – $77^{\circ}$  zones. See the *Phase I Proposal Instructions* for a detailed presentation of the CVZ scheduling opportunities as a function of celestial position, a discussion of several constraints on CVZ observing, and advice on its suitability for a given program.

### 13.2 South Atlantic Anomaly

Above South America and the South Atlantic Ocean lies a lower extension of the Van Allen radiation belts called the South Atlantic Anomaly (SAA). No astronomical or calibration observations are possible during passages of the spacecraft through the SAA because of the high background induced in the detectors. SAA passages limit the longest possible uninterrupted exposures, even in the CVZs, to about 14 hours (or 9 orbits).

### 13.3 Spacecraft Position in Orbit

Because *HST*'s orbit is low, atmospheric drag is significant. Moreover, the amount of drag varies, depending on the orientation of the telescope and the density of the atmosphere, which depends on the level of solar activity. The chief manifestation of this effect is that it is difficult to predict in advance where *HST* will be in its orbit at a given time. The position error may be as large as 30 km within two days of a determination of the position of the spacecraft in its orbit. A predicted position 44 days in the future may be up to  $\sim 4000$  km (95% confidence level) in error.

This positional uncertainty affects observers of time-critical phenomena, since the target could be behind the Earth at the time of the event. In the worst case, it will not be known if a given event will be observable until a few days before the event.

## 14. Guide Stars and Target Acquisition

As described in §11.2, *HST* uses guide stars located at the edge of its field of view. Unlike ground-based telescopes, however, *HST* uses *two* guide stars in order to control the pitch, yaw, and roll axes of the telescope. (It is also possible to control the telescope pointing in pitch and yaw with one guide star, with the rate gyros controlling the roll angle.) The guide star(s) are selected in advance by STScI for each observation.

### 14.1 Guide Stars

Selection of guide stars (GSs) is carried out by the Guide Star Selection System (GSSS) at STScI; hence most GOs only need to supply accurate coordinates for their targets, as described in §14.2. However, an understanding of the GSSS is useful to observers, since most GOs will have to use GSSS resources in Phase II to determine the accurate coordinates.

#### 14.1.1 Overview

For each scheduled *HST* observation, GSSS provides positions and magnitudes for pairs of GSs in the range  $9.0 \leq m_V \leq 14.5$ , determined from Schmidt survey plates. The following specific data are provided by GSSS:

- Relative positions of GSs with an accuracy of  $\pm 0''.5$  in the northern hemisphere and  $\pm 0''.8$  in the southern hemisphere
- GS magnitudes with an accuracy of  $\pm 0.4$  mag in the FGS magnitude system (based on the spectral response, 4600 to 7000 Å, of the FGS optics and detector)

#### 14.1.2 The Guide Star Catalog

The required whole-sky coverage made it necessary for STScI to assemble a collection of survey plates as the basis for construction of a catalog of GS candidates. For the northern hemisphere (for which proper motions have now outdated the *Palomar Sky Atlas*), a special "Quick-V" survey was conducted for STScI with the 1.2-m Schmidt telescope at Palomar Observatory. The equatorial region and the southern hemisphere are covered by the SERC-J survey and its equatorial extension.

The *Guide Star Catalog* (GSC), which resulted from the digitization and analysis of the plate collection, contains information, including coordinates and magnitudes, on about 18 million objects to 14.5 mag.

### 14.2 Target Coordinates and GASP

The observation summary that is part of each Phase I observing proposal must include celestial coordinates for all fixed targets, but these coordinates need only be of sufficient accuracy for the scientific and technical reviews described in §6 (i.e., about  $\pm 1'$ ). (For solar-system targets, see §14.4.)

As part of the Phase II information that will be required from all successful proposers, GOs will be asked to provide target coordinates that are sufficiently accurate for the actual *HST* acquisitions and observations. Because of the small instrument apertures, it should be noted that in many cases the target coordinates supplied in Phase II will have to be accurate to better than  $\pm 1''$ , and will have to be on the GSC coordinate system.

The coordinates for stellar targets that are contained in the GSC and in standard positional catalogs (SAO, AGK3, etc.) are sufficiently accurate for *HST* observations. For fainter objects, GOs should plan to use the GSSS Astrometric Support Package (GASP) software that is available at STScI for determining coordinates of any objects visible on the plate collection in the reference frame of the GSC. Details on usage of the GSC and GASP will be provided as part of the Phase II information package sent to successful proposers.

Stellar proper motions (and parallaxes) will also be requested during Phase II, since even relatively small stellar motions may be surprisingly significant. For example, a proper motion of  $\sim 0''.06 \text{ yr}^{-1}$  would be sufficient to move a target out of the FOS acquisition aperture for an epoch difference of  $\sim 35$  years. Since GASP is presently capable of providing proper motions only in some parts of the sky, Phase II proposers should be prepared to supply such information themselves.

### 14.3 Target-Acquisition Methods

In general, an astronomical target must be "acquired" (i.e., precisely centered in the appropriate instrument aperture) before *HST* can make any scientific observations of it.



Proposers should determine the appropriate acquisition strategies for their scientific observations. The acquisition overhead times should be allowed for in the calculation of the required number of spacecraft orbits, as discussed in the *Phase I Proposal Instructions*.

Four different methods are available for target acquisition, depending on the SI used, its aperture sizes, and the accuracy with which the target coordinates are known. The following subsections give an overview of target-acquisition techniques; special considerations that arise for solar-system targets are discussed in §14.4. Details are discussed in the *Instrument Handbooks*.

#### 14.3.1 Interactive Acquisition

For an interactive acquisition, *HST* is moved to a nominal position near the target, an acquisition image is obtained and transmitted to the ground, and the field is displayed for the observer. The displayed image could be from the WFPC2 or FOC, or could be a "pseudoimage" from the FOS or GHRS. The observer will then select the desired target or position. The observer is expected to be present at STScI, unless arrangements have been made to assign decision authority to an Operations Astronomer.

When the selection has been made, offsets to center the target in the desired SI aperture are calculated, the telescope is moved, and observations begin. (The scientific observation could possibly involve a different SI from the acquisition observation; e.g., the WFPC2 could be used to generate acquisition images for one of the other SIs. In practice, however, this can be done only under special circumstances because in general the guide stars would move out of the FGS FOV when the second SI is pointed at the target.)

Interactive target acquisition places significant demands on scheduling and data transmission, so that use of this method should be made only when necessary. This method is intended primarily for moving targets, variable objects, and targets of opportunity. Non-transient objects can usually be acquired with one of the other more efficient methods discussed below.

#### 14.3.2 Early Acquisition

In many cases it is possible to avoid an interactive acquisition by requesting an "early acquisition," typically with the aim of determining an accurate offset from a nearby brighter object, which can then be acquired more easily by an onboard acquisition. In this case, an acquisition image of the target is taken six or more weeks before the actual observation, permitting the GO to identify the desired target and measure the offset. An early acquisition will normally be appropriate for very faint objects or objects that are unresolved from the ground; it should not be requested in cases where the information could be obtained from ground-based observations.

It may occasionally happen that a proposer requests an acquisition image that is already contained in a GTO program, which would be protected according to the NASA policies outlined in §3.6; if an early-acquisition image is determined to be in conflict with a protected GTO image, the GO-requested image may still be permitted, but may only be used for acquisition purposes.

#### 14.3.3 Onboard Acquisition

Onboard acquisition is the only acquisition method available for the FGS, and is the preferred method for FOS and GHRS. It is not available for the WFPC2 or FOC. The telescope will be pointed so as to place the specified target position within the appropriate

acquisition aperture of the relevant instrument. Onboard software will determine the precise position of the object and then center it in the acquisition aperture. This centering could, if desired, be followed by an offset to another aperture or to another object.

#### 14.3.4 Blind Acquisition

When this method is used, the telescope is pointed to the target coordinates provided by the observer, and the observations begin without any further telescope maneuvers. This method is appropriate only when the target coordinates are known to  $\sim 10\%$  of the size of the instrument aperture. It is the preferred method with the WFPC2 and FOC, except when the observer wishes to place a target precisely on the FOC occulting fingers (in which case an interactive acquisition should be used).

### 14.4 Solar-System Targets

Objects within the solar system have apparent motions with respect to the fixed stars. *HST* has the capability to point at and track moving targets, including planets, their satellites, and surface features on them, with sub-arcsecond accuracy. However, there are a variety of practical limitations on the use of these capabilities that must be considered before addressing the feasibility of any particular investigation.

Two specific aspects of solar-system observations are discussed below: the initial acquisition of a moving target, and the subsequent tracking of the target during the scientific observations. Only an overview of the current moving-target capabilities is given here. Phase I proposers are encouraged to consult the moving-target contact persons at STScI (see Appendix A1) for more detailed information.

#### 14.4.1 Tracking Capabilities

*HST* is capable of tracking moving targets with the same precision as for fixed targets (see §11.2). This is accomplished by maintaining FGS Fine Lock on guide stars, and driving the FGS star sensors in the appropriate path, thus moving *HST* so as to track the target. Tracking under FGS control is technically possible for apparent target motions up to  $5 \text{ arcsec s}^{-1}$ . In practice, however, this technique becomes infeasible for targets moving more than a few tenths of an  $\text{arcsec s}^{-1}$ . It is currently possible to begin observations under FGS control and then switch over to gyros when the guide stars have moved out of the FGS field of view. If sufficient guide stars are available, it is possible to "hand off" from one pair to another, but this will typically incur an additional pointing error of about  $0''.3$ .

Targets moving too fast for FGS control, but less than  $7.8 \text{ arcsec s}^{-1}$ , can be observed under gyro control, with a loss in precision that depends on the length of the observation.

The track for a moving target is derived from its orbital elements. Orbital elements for all of the planets and most of their satellites are available at STScI. Moreover, STScI has access to the ASTCOM database, maintained by the Jet Propulsion Laboratory (JPL), which includes orbital elements for all of the numbered asteroids and many periodic comets. For other objects, the GO must provide orbital elements for the target in Phase II.

#### 14.4.2 Acquisition Techniques

The most difficult aspect of *HST* observations of moving targets is the acquisition of the target prior to the scientific observations. The choice of acquisition strategy can have a very large impact on the observing efficiency of a given program. Blind acquisitions are the most efficient method, but can result in  $1\sigma$  pointing errors of  $\sim 1\text{--}2''$ . Observations made

with apertures of this size (or smaller) therefore require use of an onboard or interactive acquisition. Of these two, onboard acquisition is preferred because it takes less time. However, the onboard acquisition capabilities vary significantly depending upon the SI being used and the size of the target. Generally, accurate onboard acquisitions are possible if the target diameter is smaller than 2". Nuclei of comets can be acquired with onboard acquisition only with the FOS.

Onboard acquisitions of a giant planet are best done by first acquiring one of its satellites, and then offsetting to the planet. The technique of last resort (which provides the most flexibility) is an interactive (real-time) target acquisition. This method has the greatest demands on spacecraft time, and thus should be used sparingly.

#### 14.5 Offsets and Spatial Scans

Offsets (using the same guide stars) can be performed to an accuracy of about  $\pm 0''.02$ . The sizes of offsets are limited by the requirement that both guide stars remain within the respective FOVs of their FGSs.

It is also possible to obtain data while *HST* scans across a small region of the sky. In all cases the region scanned must be a parallelogram (or a single scan line). Two types of "spatial scans" (i.e., raster scans) may be requested:

- *Continuous scan.* In this case, data are continually obtained while the telescope is in motion.
- *Dwell scan.* In this case, the telescope stops its motion periodically during the scan, and data are obtained only when the telescope is not in motion.

The possible scan area is limited by the requirement that the same guide stars be used throughout the scan, and the maximum possible scan rate for continuous scans is 1 arcsec s<sup>-1</sup>. Continuous spatial scan lines cannot be interrupted and must therefore be completed within one orbital target-visibility period. Spatial scans requiring more than 45 minutes of spacecraft time should be avoided.

### 15. Real-Time Observing

A limited capability is available for real-time interactions during *HST* observing.

Interactive acquisitions (§14.3.1) and small maneuvers are permitted in real time. The latter are typically used to improve the telescope pointing, and to implement safety checks prior to using a sensitive instrument on a bright target. The need for improved pointing arises most often for solar-system targets because of uncertainties in the target's ephemeris and because *HST* orbital decay causes changes in the times of observations after the planning and telescope scheduling have been completed. In general, the size of all real-time maneuvers is limited by the requirement that the same pair of guide stars be used to accomplish all such pointings.

There is no capability to initiate an unscheduled observation via real-time commands.

Real-time interactions with *HST* make use of the Observation Support System (OSS) at STScI. The GO will make a maneuver decision based on evaluation of the data transmitted to the ground, and the appropriate command request will be sent from OSS to the control center at Goddard Space Flight Center. As described in §7.4, STScI OAs and SOSs will be present to assist the GO in the use of OSS capabilities and to execute the command requests.

## 16. Target-of-Opportunity Observations

Some target-of-opportunity programs (see §3.1.2) will require that observations begin as soon as possible upon notification of the occurrence of an event. This section addresses various constraints that apply to such programs. Because of the major disruption of the *HST* observing schedule and attendant loss of observing efficiency, target-of-opportunity interruptions are limited to no more than ten events per year.

When notifying STScI of the appearance of the target of opportunity, the GO will provide the accurate target position. If there is uncertainty in the filter, exposure time, or other exposure parameters, the Phase II proposal should include a selection of preplanned contingencies from which the observer will make a selection.

A review of the completed proposal will be made to assure the safety of the observations, to verify that the program complies with the original observing-time allocation and scientific objectives, and to identify a breakpoint in the presently executing Science Mission Specification (SMS). After approval by the Director, the program will be entered into the scheduling system, the SMS will be re-planned to contain the new observations, and the commands will be generated to conduct the observations. The beginning of the observations of the target of opportunity must be delayed sufficiently to allow the new commands to be generated, to uplink the commands to the spacecraft at an available opportunity, to bring the required SIs from hold to operate mode (if necessary), and to slew the telescope to the target of opportunity.

The time necessary to conduct these activities will vary with the particular circumstances, but the minimum response time will be roughly 2–5 days, and this will be achievable only if *all* details of the proposal (except the target position) are available in advance. If the program requires submission of a new, detailed Phase II proposal, then the response time will be at least of order one week.

## 17. Parallel Observations

Parallel observations (see §4.2) provide a mechanism for increasing the productivity of the *HST* observatory. This section summarizes some technical aspects of parallel observing. A discussion of designation of generic targets for parallel observations is given in the *Phase I Proposal Instructions*. The effective aperture locations are listed in Table 4 and shown in Figure 3.

Parallel observations are not permitted to interfere significantly with primary observations; this restriction applies both to concurrent and subsequent observations. Some examples of this policy are the following:

- The parallel observation will not be made if its inclusion would shorten the primary observation.
- Long broadband parallel exposures with the cameras at low galactic latitudes, which could leave residual images from bright stars that would contaminate subsequent observations, will not be scheduled.
- Parallel observations will have lower priority on stored command capacity and on telemetry data volume.

The WFPC2 and FGS are the only instruments that may be used for pure parallel programs. Pure parallel observations with the WFPC2 may be scheduled with any primary instrument except the GHRS. FGS observations may be obtained in parallel with any other SI.

The WFPC2 and FOC  $f/96$  cameras may be used together for coordinated parallel observations (within the same proposal).

Because of scheduling difficulties, it is advantageous for parallel programs to request no more than one parallel exposure per orbit.

The spacecraft computers automatically correct the telescope pointing of the primary observing aperture for the effect of differential velocity aberration. This means that image shifts at the parallel aperture during an exposure of 10 to 20 mas can occur. The effect of the shift can be minimized for coordinated parallel observations by using the SI with the lower spatial resolution for the parallel exposure.

## APPENDICES

### A1. STScI and ST-ECF Staff Contacts

(unless otherwise indicated, telephone numbers are 410-338-xxxx)  
(e-mail addresses are usually lastname@stsci.edu; contact usb@stsci.edu if this fails)

Director's Office		
Director	Robert E. Williams	4710
Deputy Director	H. S. Stockman	4730
Assoc. Director for Operations	Ethan Schreier	4740
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## A2. Funding Policies

It is anticipated that funds will be made available to STScI by NASA for the direct support of Cycle 5 *HST* research by U.S. scientists. This appendix discusses the general conditions under which such funding will be awarded.

### A2.1 Eligibility for STScI Grant Funds

Funding from STScI may be requested by scientists who are (1) United States citizens residing in the U.S., or abroad if salary and support are being paid by a U.S. institution; (2) U.S. permanent residents and foreign-national scientists working in and funded by U.S. institutions in the U.S.; or (3) U.S. Co-Investigators (Co-Is) on observing projects with non-U.S. Principal Investigators (PIs).

Proposals for funding will be accepted from Universities and other nonprofit research institutions, private for-profit organizations, Federal employees, STScI employees, and unaffiliated scientists. For-profit organizations should note that profit is not an allowable cost for GO/AR grants.

STScI encourages collaboration by scientists from different institutions in order to make the best use of *HST* observing time and STScI financial support. Where multiple organizations are involved, it is normally required that the proposal be submitted by only one institution, with one scientist designated as PI with full responsibility for the scientific and administrative organization of the project. The proposal should clearly describe the role of the other institutions and the proposed managerial arrangements. STScI will award funding to the designated PI institution and to the Co-I institutions. In special circumstances, a single grant may be awarded to the PI institution, which will provide Co-I funding through subgrants or subcontracts.

When a U.S. PI obtains grant funds from STScI for a project involving non-U.S. Co-Is, no funding may flow through the U.S. PI to the non-U.S. Co-Is.

U.S. Co-Is requesting funds for a proposal submitted by a non-U.S. PI are required to submit the Phase II budget forms through one of the Co-I institutions. Approved funding will be awarded by STScI directly to the Co-I institutions.

### A2.2 Allowable Costs

Support may be requested for the acquisition, calibration, analysis, and publication of *HST* data, and related costs.

The following costs are allowable:

1. *Salaries and wages.* Salary support for project investigators is allowable, provided it is consistent with the policies of the institution assuming responsibility for the grant.

STScI funds may not be used to pay more than a person's full-time salary or to pay more than an individual's hourly rate. Also, an individual may not be reimbursed for consulting or other work in addition to a regular full-time institutional salary covering the same period of employment. For faculty members in academic institutions, STScI funding will normally be limited to no more than two months of summer-salary support. Exceptions for released time during the academic year may be permitted in special circumstances, but such costs must be fully justified in the proposal.

Released time for project investigators working in non-academic institutions is allowable, provided the compensation requested is reasonable and consistent with each employee's regular full-time salary or rate of compensation.



It is assumed that most scientists will be affiliated with, and apply to STScI through, institutions that will make substantial support available for project activities (e.g., computer facilities, collaboration with other scientists, students, or research assistants). Salary support may be requested for unaffiliated scientists, but must be justified in the proposal, preferably in terms of the scientist's salary while most recently affiliated with an institution, or the salary that would be received if the scientist were currently employed on a full-time basis rather than working on the *HST* project.

2. *Research assistance.* Reasonable costs for graduate students, post-doctoral associates, data aides, and secretarial and technical support for the analysis of *HST* data are allowable. For post-doctoral associates and other professionals, each position should be listed with the number of months, percentage of time that will be spent on the project, and rate of pay (hourly, monthly, or annual). For graduate students and secretarial, clerical, and technical staff, only the total number of persons and the total amount of salaries per year in each category are required. All such salaries must be in accordance with the standard policies of the institution assuming responsibility for the project.

3. *Fringe benefits.* If an institution's usual accounting practices provide that its contributions to employee "benefits" (Social Security, retirement, etc.) be treated as direct costs, STScI funds may be requested for all applicable fringe benefits.

4. *Publication costs.* Reasonable costs for publication of research results obtained from the analysis of *HST* data are allowable.

5. *Travel.* Transportation and subsistence costs for project personnel to obtain, analyze, and disseminate direct results of *HST* observations are allowable, provided such costs have been justified in the proposal and fully detailed in the budget. Such costs must be in accordance with the written travel policies of the institution assuming responsibility for the project. In lieu of an institutional travel policy, the Federal Travel Regulations may be used for guidance.

6. *Computer services.* The costs of computer time and software for the analysis of *HST* data are allowable. Details of the services and software that will be used must be fully described and justified in the proposal.

7. *Permanent equipment.* The purchase of permanent equipment (items costing over \$1000), including computers or related hardware, will be approved in special circumstances, and a detailed justification must be provided in the proposal. If such equipment is requested, the proposal must certify that the equipment is not otherwise available to project personnel, and/or that the cost of renting the equipment (or usage charges) would exceed the purchase price. It is expected that, in most instances, the recipient organization will provide at least half of the purchase price of any item costing over \$10,000.

Unless stated to the contrary in the Grant Award Document, title to and all responsibility for equipment purchased with grant funds will be vested in the grantee institution, provided that the grantee uses the equipment for the authorized activities of the project and provided that the grantee agrees to transfer title to the equipment to the designee of STScI or NASA if a request for such transfer should be made within 120 days after the completion of the project. However, if the grantee organization has provided at least half of the purchase price of the equipment, STScI will vest title to such equipment in the grantee institution. Normally, the purchase of equipment will not be approved in grants to unaffiliated individuals or for-profit organizations.

8. *Materials and supplies.* Materials and supplies directly related to the analysis of *HST* data are allowable, provided such costs are not already reimbursed through indirect costs.

9. *Funds to support ground-based observations.* Funding for preparatory observations is allowable for the acquisition of astrometric data to obtain accurate target positions for an observer's approved *HST* program. Ground-based observations that are clearly essential to the interpretation of *HST* observations are also allowable. A description and justification of the planned observations must be provided in the Budget Narrative Form submitted in Phase II. The total cost of the ground-based observations must be only a small portion of the overall budget to analyze *HST* data.

10. *Indirect costs (IDCs).* Indirect costs are allowable, provided that the IDC rate used in the budget is based on a Negotiation Agreement with the Federal Government. STScI will exclude from the indirect cost base all subcontracts and subgrants in excess of \$10,000. Should funding be approved for the project, the grantee will be requested to submit one copy of the Federal IDC Negotiation Agreement to the STScI Grants Administrator.

For institutions without a negotiated rate, STScI may allow a charge of 10% of direct costs, less items that would distort this base, such as major equipment purchases. However, the charge must not exceed \$5,000 and documentation must be available to support the amount charged. Alternatively, such institutions may show such expenses as direct costs to the project, provided documentation will be maintained to verify such costs. Unaffiliated scientists should not use an indirect cost rate; instead, all administrative costs should be shown as direct costs of the project.

### **A2.3 Budget Submission**

Submission procedures are described in the *Phase I Proposal Instructions*.

Questions concerning funding policies and the budget forms should be directed to the STScI Grants Administration Branch.

### **A2.4 Preparatory Funding**

General Observers are strongly encouraged to request early funding of their programs to prepare for the receipt of *HST* data. Proposers may request up to 25% of the funds for their programs to be awarded prior to the start of the Cycle 5 observing schedule. Preparatory funding may be requested in item 11 on Budget Form GF-95-2 when the budget is submitted in Phase II. Note that the preparatory funds are part of the overall funding allocated for the program, not additional funds.

### **A2.5 Grant Period**

It is anticipated that STScI will award grants for periods of one to two years, depending on the nature and complexity of the project, to complete the analysis of the current cycle's observations. If the requested grant period is for more than one year, funding for the project will be on an annual basis, with additional funding for each subsequent grant year awarded after a favorable review of an annual performance report that will be required.

Long-term projects that are approved for more than one cycle of observations will be funded on an annual basis. Such programs require an annual continuation proposal, as described in §3.1.3, and will be reviewed by the TAC. A budget for the analysis of current Cycle observations must be submitted with an estimate of the funding requirements for

subsequent Cycles. Funding for subsequent Cycles will be provided through an amendment to an existing STScI grant.

## **A2.6 Award of Funds**

Shortly before the start of Cycle 5, each PI will receive notification from the Director concerning the specific funding allocation for their GO program. It is anticipated that requests for preparatory funding will be awarded prior to the start of Cycle 5. Additional funding up to the approved funding allocation will be awarded after the receipt of observational data for each GO program.

## **A2.7 Archival Research**

See the *Phase I Proposal Instructions* for details.

## **A2.8 Educational Supplements**

Funded *HST* proposers are invited to apply to the Astrophysics Grant Supplements for Education (AGSE) program, which is sponsored and funded by NASA Headquarters. This program provides a modest supplement (\$6,000) to existing NASA Astrophysics or STScI grants in order to enhance the participation of research astronomers in pre-collegiate or public outreach activities. All current Principal Investigators funded through the NASA Astrophysics Division or STScI are eligible to apply for an AGSE award. For more information, contact Dr. Cherilynn A. Morrow, Astrophysics Division, Code SZ, NASA Headquarters, Washington, DC 20546.

# **A3. Scientific Instruments Retired at End of Cycle 3**

The following subsections describe the two instruments that were removed from *HST* during the servicing mission. The information may be of use to persons proposing Archival Research. §9 gives estimates of the amount of archival data available from these instruments.

## **A3.1 Wide Field and Planetary Camera (WF/PC)**

The WF/PC had two configurations; in both, the FOV was covered by a mosaic of four charge-coupled devices (CCDs). Each CCD had  $800 \times 800$  pixels and was sensitive from 1150 to 11,000 Å. However, internal contaminants on the camera optics limited normal operation to the range from 2840 to 11,000 Å.

In the Wide Field Camera (low-resolution) configuration, the FOV was  $2'.6 \times 2'.6$ , with a pixel size of  $0''.10$ . In the Planetary Camera (high-resolution) configuration, the FOV was  $1'.1 \times 1'.1$ , and the pixel size was  $0''.043$ . A variety of filters was available.

## **A3.2 High Speed Photometer (HSP)**

The HSP was designed to take advantage of the lack of atmospheric scintillation for a telescope in orbit, as well as to provide good ultraviolet performance. Integrations as short as  $10 \mu\text{s}$  were possible, over a broad wavelength range (1200 to 8000 Å), and polarimetry was also possible. Observations were carried out through aperture diameters of  $1''.0$  with the visual (VIS) and ultraviolet (UV) detectors, and  $0''.65$  with the polarimetry (POL) detector.

HSP had a large variety of fixed aperture/filter combinations distributed in the focal plane; selection was accomplished by moving the telescope so as to place the target in the desired aperture behind the desired filter.

The HSP detectors were four image-dissector tubes (IDTs) and one photomultiplier tube (PMT). A variety of ultraviolet and visual filters and polarizers was available.

#### A4. Acronyms and Abbreviations

AEC	Archived Exposures Catalog
AGK3	<i>Astronomische Gesellschaft Katalog</i>
AR	Archival Research
AURA	Association of Universities for Research in Astronomy, Inc.
CADC	Canadian Astronomy Data Centre
CCD	Charge-Coupled Device
CDB	Calibration Data Base
Co-I	Co-Investigator
COSTAR	Corrective Optics Space Telescope Axial Replacement
CVZ	Continuous Viewing Zone
DADS	Data Archive and Distribution System
DD	Director's Discretionary
DMF	Data Management Facility
ESA	European Space Agency
FGS	Fine Guidance Sensor
FITS	Flexible Image Transport System
FOC	Faint Object Camera
FOV	Field of View
FOS	Faint Object Spectrograph
ftp	File Transport Protocol
GASP	GSSS Astrometric Support Package
GHRS	Goddard High Resolution Spectrograph
GO	General Observer
GS	Guide Star
GSC	<i>Guide Star Catalog</i>
GSFC	Goddard Space Flight Center
GSSS	Guide Star Selection System
GTO	Guaranteed Time Observer
HSP	High Speed Photometer
<i>HST</i>	<i>Hubble Space Telescope</i>
IDC	Indirect Cost
IDT	Image Dissector Tube
IRAF	Image Reduction and Analysis Facility
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
NOAO	National Optical Astronomy Observatories
OA	Operations Astronomer
OSS	Observation Support System
OTA	Optical Telescope Assembly
PC	Planetary Camera

PCS	Pointing Control System
PI	Principal Investigator
PMT	Photomultiplier Tube
PSF	Point-Spread Function
RSDP	Routine Scientific Data Processing
SAA	South Atlantic Anomaly
SAO	Smithsonian Astrophysical Observatory
SDA	Science Data Analyst
SI	Scientific Instrument
SOS	Science Operations Specialist
SPSO	Science Program Selection Office
SPSS	Science Planning and Scheduling System
SSM	Support Systems Module
ST-ECF	European Coordinating Facility for Space Telescope
STEIS	Space Telescope Electronic Information Service
STOCC	Space Telescope Operations Control Center
STScI	Space Telescope Science Institute
STSDAS	Space Telescope Science Data Analysis Software
TAC	Telescope Allocation Committee
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
URL	Universal Resource Locator
USB	User Support Branch
WFC	Wide Field Camera
WF/PC	Wide Field and Planetary Camera (1)
WFPC2	Wide Field Planetary Camera 2
WWW	World-Wide Web

